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UNIVERSAL

GEOGRAPHY,

OR

A DESCRIPTION

OF

84313

ALL THE PARTS OF THE WORLD,

ON A NEW PLAN,

ACCORDING TO THE GREAT NATURAL DIVISIONS OF THE GLOBE;

ACCOMPANIED WITH

ANALYTICAL, SYNOPTICAL, AND ELEMENTARY TABLES.

BY M. MALTE-BRUN.

IMPROVED BY THE ADDITION OF THE MOST RECENT INFORMATION, DERIVED FROM VARIOUS SOURCES.

VOL. I.

CONTAINING THE THEORY, OR MATHEMATICAL, PHYSICAL, AND POLITICAL PRINCIPLES, OF GEOGRAPHY.

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THE AUTHOR'S PREFACE.

THE design of the present Work is, to bring together, in a series of historical discourses, the whole of Ancient and Modern Geography, in such a manner as to furnish the reader with a lively picture of the whole terraqueous globe, with all its different countries — the memorable places which they contain — the tribes of men by which they have been successively peopled, and those which at the present moment are its inhabitants. It appears an immense undertaking, when we consider how many varied details require to be combined in a work of moderate size. It might even appear rash in its nature, when we contemplate the characters of the different subjects embraced in it—subjects which have usually been consigned to erudite rather than to elegant pens, and have been regarded as sus-

ceptible of no brilliancy of literary composition, or depth of philosophical remark.

The diffidence which the prospect of so many difficulties naturally creates, has, however, yielded to a thorough conviction, that the science of geography admits of being made very different from what it now is. We have thus reasoned: Is not geography the sister and the rival of history? If the one enjoys the empire of universal time, does not the other rightfully claim that of place? If the one has the power of recalling past generations, should not the other exert that of fixing in one scene the shifting pictures of history, by delineating to the mind the permanent theatre of the poor and brief transactions of mankind, strewed with the wrecks of numerous empires; and describe the course of nature, constantly occupied in repairing, by its beneficial operation, the ravages arising from human discord? Does not a description of the globe intimately connect itself with the study of human nature, human manners, and human institutions? Does it not offer information of the utmost importance to the political sciences? Is not this department always brought fully into view before a complete form can be given to any branch of natural history? And does it not supply literature with a boundless treasure of feelings and of images?

These considerations have cherished in our

minds the hope of raising for geography a monument not unworthy to rank along with the pleasing compositions by which history has been adorned. Many long years would indeed be requisite to confer on such a work that degree of perfection which it is natural to desire. In publishing it in a state short of this, we find ourselves excused by the urgent demands made on us for a "Treatise on Geography." The attempt now laid before the public will, we hope, with all its imperfections, satisfy the wishes of those who complain that there is an absolute want of a work by which geography may be learned, without the risk of contracting a permanent disrelish for this branch of instruction.

We presume to trust that our compend may be qualified to serve as a guide to any professor who is ambitious of teaching geography in a profitable manner;—that in the more advanced seminaries it may be put into the hands of pupils;—and that it will not be an unacceptable present to adults, who have long passed their period of tuition, and wish to acquire instruction by private reading.

It is the Author's most ambitious wish, that his work may obtain the suffrages of those real philosophers, who, in every science, set even less value on its useful economical results, than on the intellectual enjoyment and the improvement which the study of it implies.

The following is the arrangement of the present work: It will begin with the general theory of geography, consisting of its Mathematical, Physical, and Political principles.—From astronomy we shall borrow the requisite information, respecting the figure, size, and motions of our planet; from geometry, the views which are most necessary for understanding the art of representing, in small plans, the exact form of the lands and the seas: we shall explain the method of determining the actual distances of places, and comparing with one another the measures employed in different countries.

Proceeding next to the physical picture of the globe, we shall take a view of the leading features of nature; the mountains which diversify the surface of the land, the seas which bound its outline, and the rivers and the valleys by which it is intersected. We shall seek our way downward, through caverns and through mines. We shall direct over the brink of the volcanic crater an eye of interest and curiosity; and thus do our utmost to explore the structure of the globe. After inquiring into the motions of the atmosphere, and the laws of temperature, we shall distribute into their native regions the animals, the plants, and all the beings that are nourished in the exhaustless bosom of the earth. We shall conclude the picture by considering man in his natural and in his political condition. We shall classify the races of our species ac-

cording to the varieties which are marked in their bodily appearance and character—according to the languages which they speak—according to the creeds by which their minds are consoled, or degraded and enslaved—and according to the laws which mark the progress of civilization, or the profound darkness of utter barbarism.

What revolutions has the terrestrial globe undergone? This is a question which equally interests the history of man and that of nature. But is it a question which enters into the science of physical geography? is it a question which, in the present state of our knowledge, we can profitably discuss? We shall not certainly undertake to resolve the problem, or series of problems, which it implies; but we shall present to our readers a view of the leading facts which geologists employ to construct their brilliant, but empty systems.

This philosophical theory of geography will occupy the first volume of our work. The others, with the exception of one, will be devoted to a successive description of all the parts of the world. In that department we found it necessary to engage in long meditation, and in weighing opposite considerations, before we could invent and fix upon the method which would unite the greatest degree of solidity with the most agreeable manner. An order purely

geographical must apparently have destroyed the political and moral connections of the different portraits which we had to present. An order purely political would have injured the physical delineation of the mountains, the seas, the rivers, and the climates. The great desideration was, to reconcile, in some measure, with each other these two rival methods. For this purpose, our mode of procedure must be varied according to the character of the obstacles presented on different occasions, and the difficulties which they create in following chiefly or exclusively one or the other of these two methods. In introductions prefixed to particular departments, we must give a sketch of the general features which a large division of the world possesses in common. We must place a view of the Alps in front of our description of Europe, and a view of the Cordilleras at the beginning of the division appropriated to South America. Do we find some nations which are politically separate, united in their origin, in their language, or in their history?—we must collect them into one group, and survey them from one point of view. We must endeavour everywhere to form our subject into natural masses, easily embraced under one regular vista. Small states must be combined into natural groups; the provinces of great empires must be distributed in conformity with the direction of the mountains and the rivers; and the comparisons formed between the different divisions must not be per-

mitted to encumber the current of our discourse, but reserved for exhibition in the form of synoptical and analytical tables.

Besides our general arrangement, it was necessary to find out the particular method best suited for the description of each country. After examining all the classifications which authors have given of the objects of special geography, we have found that a too rigorous adherence to these abstract methods has been the real cause of the pedantic dryness attached to books of geography. From this empty technical parade of science, geography, which ought to be a living picture of the universe, has been converted into the gloomy anatomy of a great subject in a dead and dismembered state. Thus it has been held in dread by the young, neglected by the learned, and scorned by the multitude.

From these considerations it has appeared our duty to follow the general principles of the art of writing, and, by varying according to the nature of the subject, not only the tone but the order of our descriptions, we have endeavoured to contrive, for the delineation of each country, a particular scale suited to the relative size and importance of its objects. Where one presents the spectacle of a smiling cultivation, we give a careful detail of its different productions. Where it is uncultivated, we draw an outline

of the character impressed on it by nature. At one time, in an imaginary tour, we give an easy enumeration of the towns of the interior. At another, in the character of fire-side navigators, unfettered by the dread of contrary winds or dangerous currents, we proceed from harbour to harbour, and from island to island. Does a particular nation act a leading part in the civilized world?—we discuss its powers, its resources, its interests. Is it a savage horde that engages our notice?—we take an interest in depicting its manners and mode of living.

Our choice of the towns and remarkable places on which we dwell, will be determined sometimes by degrees of political importance, sometimes by historical celebrity. We shall sometimes, in passing, take the liberty of discussing a point of critical geography, resolving a doubt, or correcting an error. We shall not even scrupulously deny ourselves and our readers the pleasure of occasionally mingling our topographical descriptions with passages of history, or with anecdotes tending to illustrate manners, and often serving to fix in the memory names of localities, which otherwise it would be difficult to retain. There is no reason why we should refuse to pick up a flower which obtrudes itself on our view. A description of the world should resemble the world itself, in which the most arid deserts present here and there a limpid fountain, or a refreshing shade.

From fifteen years of geographical reading and study, we have been fully convinced that this free and animated march is that which will enable geography to give the surest access to the sanctuary of historical knowledge, which never could be afforded by any of those rigid abstract methods which are applicable only to the mathematical sciences. Our object is to write an agreeable and useful book, not to draw up an extended table of mere contents.

Adopting this plan for our "Universal Geography," we are far from denying the merits of methods different from our own. Let a new Varenius, in a purely mathematical geography, employ all the resources of the higher geometry; let another Bergmann discuss, in the language of chemistry and of natural history, the elements of an improved physical geography; let naturalists subdivide physical geography itself into branches corresponding to particular sciences, as the geography of plants, of minerals, and of animals; let the pupils and successors of Busching collect, with indefatigable patience, the materials of chorography and topography, the object of which is to give a particular description of each country, each canton, and each town; let them display, in immense columns of numbers, the details of that branch of political geography which is called statistics. Let others of the learned explore other parts, such as that of forming a Critical Comparison of the old geographers; or, the History of Voyages and Travels.

Nothing is more useful to science—nothing more deserving of the esteem of the learned world, than labours thus consecrated to a single object. Nothing is more laudable than to give to each of these branches the most rigorous and scientific form which its particular nature will admit of. We have already shown some zeal in collecting, announcing, and appreciating labours of these different kinds, in our periodical work, entitled, *Annales des Voyages de la Géographie et de l'Histoire.* But, as a universal geography cannot, without swelling to an undue extent, embrace all the details of every branch of geographical science, we must here content ourselves with gathering the flowers and the fruit of these learned discussions and laborious researches.

There is another view of the subject which we wish to lay before the readers of our work. The mathematical and physical principles of geography are immutable; but the state of human knowledge is variable, both in the materials furnished, and in the use which the mind is, at different epochs, qualified to make of them. Nations are extinguished, kingdoms destroyed, cities laid in ruins, and at last every trace of their former existence is effaced. We may therefore suppose a series of geographical works, each of which, though quite different from those which precede and follow, may be correct and complete for the year or the

age to which it belongs. Under this point of view, custom has in some measure sanctioned a three-fold partition of the science. "Ancient geography" comprises all that precedes the 500th year of the Christian era, or the great migration of nations. The "geography of the middle age" extends from that period to the discovery of America; and this point begins the region of "modern geography." But if the subject were to be expressed in rigidly philosophical language, we should be obliged to make a distinction of geographies, corresponding to the number of nations and of ages. Each of these may be considered as a separate body of knowledge. They are indeed imperfect and erroneous systems, compared with that of the present age; but it is interesting and important even for mere amateurs, to have an idea of the slow progress, and sometimes retrograde course of the science, in so far as that progress is known to us with certainty. We shall therefore accompany the present work with an "Outline of the history of discoveries, and of geographical systems." We shall first take up this science in her cradle. Moses and Homer present us with a picture of two most antique nations. Soon after this, the Phœnician sailor, guided by the light of the stars, traverses the Mediterranean, and discovers the Atlantic Ocean. Herodotus relates to the Greeks what he has seen and heard, concerning different nations and countries. The extensive colonial system of Carth-

age, and the adventurous voyages of Pytheas of Marseilles bring the western world into view, and create conjectures respecting the north. The military glory of Alexander throws a brilliant light on the countries of the east. The Romans inherit the greater part of the discoveries made by the polished nations of antiquity. The Eratostheneses, the Strabos, the Plinies, and the Ptolemies, arrange the materials still obscure and incomplete. Next comes the great migration of nations, to overturn the whole edifice of ancient geography. It was by losing their ascendency that the Greeks and Romans learned how much more extensive the world was than their systems had represented it. The chaos thus produced, gradually gives place to regularity; and, with the rise of modern Europe, the elements of a new geography are formed. The spirit of travelling revives. It had already conducted, without profit, the Arabs to the Moluccas, and the Scandinavians to America. No science accompanied these people, to gather the fruit of their bold undertaking. Equally courageous, and better informed, the Italians and Portuguese, by the help of the magnetic needle, navigate the high seas with confidence. On every hand the barriers raised by prejudice, which contracted the horizon of geography, fall in pieces. Columbus now conducts us to a new world. By sea and by land, every nation emulously enters on the career of discovery; and, by their united efforts,

the vast theatre of the globe, notwithstanding some partial shades, is now finally opened to the gaze of science.

This forms a subject which demands much perusal of old geographical works, and much attention to various ancient histories; but it cannot, in the eye of the general reader, be entitled to such a full description as the state of modern geography.

Even modern geography must be restricted within certain limits, which, without reducing it to a dry unmeaning nomenclature, will avoid the error of confounding it with other sciences. Intelligent minds, no doubt, often delight to bring together under the same point of view the results of sciences the most different from one another in their origin and progress, as well as in the nature of their objects. Geography, like history, certainly ought not to be blamed for taking an interest in every thing that influences the fate of nations and of empires. It must also be granted that she confers, in her turn, a benefit on other sciences, by bringing their discoveries into notice, in order to place them in a new light. When political economy, for example, weighs in her balance the powers of a state, when she ascertains the existing relation which the superficial area of each canton bears to the number of its inhabitants, the results of these laborious inquiries may often be of such a

nature as to interest history. In the same way they may also interest geography. Such dry truths, when arranged in tables of political geography, acquire a lustre and an interest from the great geographical views with which they are associated. This species of interchange gives life to the whole republic of science and of literature. But the different regions of which that republic consists, have each its own language, its constitution, its separate interests. These objects are not to be confounded. Every discussion in politics, in religion, in morality—every research in history, chronology, or antiquities, which does not bear a direct reference to geographical changes—every calculation of the higher geometry—every superfluous quotation of the principles of chemistry or of physics—every detail in natural history which does not admit of any other description than the technical explanations of the naturalist, and which forms no essential feature in the physical picture of a country—is to be considered as foreign to a good universal geography, though entering with great propriety into special treatises on mathematical, physical, or political geography.

Our science, when disencumbered of all that diversity of foreign matter, is still a subject of vast extent; and to an author desirous of exhibiting it in an advantageous light, it presents thorns and difficulties in sufficient number. When we have read, compared, and formed a judgment

on all the accounts given by travellers of every nation, accounts often false, and often unsatisfactory, when we have analyzed an immense multitude of travellers' journals, astronomical observations and dissertations, descriptions and notices, enumerations and official statements, together with the estimates and calculations made by individuals; when we have, with much labour, searched out geographical documents, lost in memoirs of natural history, in monographs of medical, mineralogical, or botanical topography, often even in commercial almanacks and political journals;—we have not yet done all that is required. Much remains to be brought to light that lies hid in the archives of governments, or buried in the portfolios of individuals; and much knowledge which is even openly exhibited in the great book of nature, but has not yet found an attentive observer, requires to be discovered by original observations.

Since geographical knowledge, like every thing of a historical nature, is derived from many sources, varying in their degrees of authenticity, it is indispensably necessary, in order to satisfy the inquiring reader, to give the names of such sources as have been consulted. The learned will thus judge what degree of credit they ought to repose in each instance. It is also an act of literary justice to make our readers acquainted with the names of those who have served as our masters and

guides; names which to many will thus become known for the first time. Influenced by these considerations, we have at the bottom of each page given a reference to the principal passages in other authors, (generally original, rarely compilers,) on which our assertions are founded. At the same time, we have rigorously avoided such foot-notes as are injudiciously lavished in many learned works. None of our references will force our readers to make a halt. While one who is critically curious may, by means of them, bring our accuracy to the test, or obtain the means of extending his information on particular parts of our subject, another, whose object is to obtain as much interesting information as possible in the easiest manner, may peruse our work without suffering himself to be in any degree impeded by the references.

SYSTEM

OF

UNIVERSAL GEOGRAPHY.

BOOK I.

Theory of Geography. Of the Earth, considered as a celestial Body, and in its relations to the other celestial Bodies. Of Latitudes and Longitudes.

In exhibiting under one view the actual state of the science of Geography, the statement of general truths ought to precede the detail of particular facts. We shall therefore consider our planet in relation to its dimensions and physical structure, before entering upon the study of the different countries which cover its surface.

It belongs to astronomy to exhibit to our view the earth balanced by its own weight in the immensity of space, revolving, with all the other planets, around the resplendent luminary, which distributes to each of these celestial globes its portion of light and heat. It belongs also to astronomy to ascertain the laws which govern the *solar system*, and to trace the orbits of the different bodies which compose it; of *Mercury*, lost in the rays of the sun; of *Venus* and of *Mars*, in the neighbourhood of our earth, but which are not attended by any *moon* or satellite; of *Vesta*, *Juno*, *Ceres*, and *Pallas*, which are so closely connected with each other; and lastly, of *Jupiter*, *Saturn*, and *Uranus*, each

Astronomy excluded from this treatise.

surrounded by a magnificent train of satellites, or *secondary planets.* It is still farther the business of the astronomer, to demonstrate that the magnitude of the sun is 1,384,462 times greater than that of our planet, which in this respect is in like manner surpassed by Jupiter 1,281 times; by Saturn 995 times, and by Uranus, 80 times; while all the other planets are inferior to it [a].

As geography exclusively is our province, it is sufficient for us to borrow such notions belonging to astronomy, as are necessary for comprehending the terms employed in reference to geographical maps, and for conceiving the truth of the methods used in constructing these representations of our globe.

Proofs of the rotundity of the earth.

The spherical form of the earth is the fundamental principle of all mathematical geography. The proofs of this truth present themselves to the senses [b]. The phenomena of the heavens discover it to us; terrestrial appearances also render it obvious. We shall begin with the latter.

Proofs drawn from terrestrial appearances.

Were we placed in a vast plain of Arabia, or on the surface of the ocean, no mountain would there intercept the objects situate within the range of our vision. Why then do we not see elevated objects only diminish in apparent magnitude, as they recede from our view, without any portion being hid; as would certainly be the case if we were upon the same horizontal plane with them? Why do towers, vessels, and mountains, when we recede from them, appear to sink below the horizon, commencing with the base? and why, on the contrary, when we approach them, do these objects shew first their summits, and thereafter their middle, and last of all their lower parts? These phenomena, which every one has an opportunity of observing, prove evidently that every apparent plane upon the earth is a curve surface. It is the convexity of this surface which conceals from the eye of the spectator, upon the beach, the

[a] See, in the Sequel of this Book, the *Synoptical Table* of the solar System. Consult *Laplace*, Exposition du Système du Monde; *Biot*, Astronomie Physique.

[b] *Varenius*, General Geography revised by *I. Newton*, b. I. sect. ii. chap. 3. *Maupertuis*, Elements of Geography, chap. 2.

hull of the vessel of which he sees the masts and sails. But since we know that these things happen uniformly towards whatever part of the earth we travel, whether towards the east or towards the west, towards the north or towards the south; since we find that this assemblage of curve surfaces is no where sensibly interrupted, it is impossible to avoid drawing the conclusion, that the whole surface of the earth is, on all sides, nearly regularly curved; or, in other words, that the earth is a body approaching in figure more or less to a sphere.

Proofs derived from celestial appearances.

The object at which the first observers of the stars aimed in their researches was, without doubt, to find certain guides in the voyages which either curiosity or necessity prompted them to undertake. They remarked that the sun, their first guide, occupied, in the celestial hemisphere, a place opposite to certain stars, which every night were constantly visible over their heads, while other stars disappeared and re-appeared alternately. Their attention was particularly attracted by the *pole star:* they marked this point in the heavens, which, itself alone immovable, appears to serve as a pivot, or, according to the Greek expression, as a *pole* [c], to the apparent motions of the heavenly bodies. They next traced a *meridian line*, that is, a right line in the direction from the sun at noon to the pole star; and however imperfect this first operation may have been, it was sufficient to mark out to them the four quarters of the world, usually denominated the *cardinal points.* Now, if they proceeded towards the north, they saw the pole star take a position more elevated in the heavens, with regard to the circle which on all sides bounded their view, and which is named the *horizon* [d]. Did they go towards the south, this same star appeared to sink, and others, before invisible, appeared successively to rise. It was therefore impossible that the line whose direction they followed, could be a straight line traced upon a horizontal plane; it could

[c] Πολος, a pivot, from πολειν, to turn.

[d] From ὁριζειν, to bound, to circumscribe.

only be a curve, an arc of a circle, to which corresponded another arc of an imaginary circle in the heavens. But as the same changes of the horizon had every where taken place, it was natural to conclude that the earth had at least a circular form from north to south.

It was without doubt by some such reasoning that Anaximander, and some other of the ancient philosophers, were led to regard the figure of the earth as *cylindrical* [e].

Astronomical observations, by being multiplied, were rendered perfect. The motions of the heavenly bodies were calculated from fixed epochs; and the periodical return of eclipses was determined. It was then easily perceived, that the sun rises sooner to those who dwell more towards the east, and gradually later to others in proportion as they are removed to the west; for if an eclipse of the moon is observed at Paris and at Vienna, and if this eclipse begin when it is ten o'clock at night at Paris, it will be near eleven o'clock at Vienna before its commencement is observed; so that the sun must rise sooner to the inhabitants of Vienna, than to those of Paris. This, however, could not happen unless the surface of the earth were curved from east to west; for were it flat, the sun would begin to illuminate all parts of the face of it at the same instant.

Lastly, when by a series of observations, we are fully convinced that the eclipses of the moon are caused by the conical shadow of the globe of the earth, we have a complete confirmation of all the preceding proofs in favour of the rotundity of the earth; and we see at the same time, that the globe of the earth is not subject to any great irregularity; since, in all possible positions, its shadow upon the disk of the moon is found to be terminated by an arc of a circle.

Confirmed by voyages round the world.

The numerous voyages which have been made round the world, have finally shut the mouths of all those who persisted in regarding the earth as a round plane, or a hemispherical disk. Navigators, such as Magellan and

[e] *Arist. de Cœlo*, lib. ii. cap. 13.

Drake, sailing from Europe, have pursued a course always towards the west (making only some deviations, in order to double the lands which stretch towards the south;) and without quitting this general direction, have returned to the same place whence they set out. Upon a circular plane we might indeed perform a circular voyage, but that by continually changing the direction. *Heemskerk*, when he wintered at Nova Zembla, confirmed what astronomers had concluded from the spherical figure of the earth;—namely, that the days and nights near the poles extend to several months. Finally, *Cook*, in approaching as near as possible to the southern polar circle, found that the voyage round was always diminished proportionably to the diminution of his distance from the pole; so that we have thus obtained an ocular proof of the rotundity of the earth towards the south pole, as well as towards the north.

Prejudices against this doctrine.

So many united proofs, as well as the accuracy of so many astronomical observations, all of which have been made and calculated upon the supposition of the sphericity of our earth, leave no room for reasonable doubts upon the subject. Respect for the Sacred Writings, which, in speaking of the earth, employ expressions borrowed from ordinary language[f], ought not to induce us to reject a physical truth altogether foreign to the moral truths which religion teaches. In vain does ignorance demand of us how the earth can remain suspended in the air without any support. Let us look upon the heavens, and observe how many other globes roll in space. The force which supports them is unknown to us; but we see its effects, and we investigate the laws according to which these effects take place. Let us then lay aside all uneasiness concerning the *antipodes*, that is, the people of the earth whose feet are turned towards ours: there is upon the globe neither high nor low; the antipodes see, in like manner as we do, the earth under their feet, and the sky over their heads.

[f] Psalm xxiv. 2. xxxvi. 6. Comp. *Lactant.* l. iii. ch. 24. *Augustin.* De Civ. Dei, XVI. 9.

What would we gain by supposing, as Homer does, that under the earth are placed a range of columns guarded by Atlas, or by imagining it to rest upon nine pillars, as the Scandinavians believed [g], or upon four elephants, according to the opinion of the worshippers of Bramah? Upon what would these elephants or these columns rest? Our thoughts, however far they proceed, must always at length stop short, and, affrighted, recoil from that infinity which surrounds us on every side, and which it is folly to attempt to comprehend. But, some more reasonable observers will say, Do not the Andes and the Alps make it evident that the earth is an irregular body, and not at all round? We answer: The highest mountain known, which is Chimborazo in Peru, rises to 21,424 [h] feet above the surface of the sea. This [i] height is nearly $\frac{1}{3000}$ of the earth's greatest circumference, and $\frac{1}{1500}$ of its axis. Upon an artificial globe of twenty-one feet in circumference, or of $6\frac{2}{3}$ feet in diameter, Chimborazo could only be represented by a grain of sand less than one-twentieth of an inch in thickness. Irregularities so imperceptible do not deserve to be taken into consideration. We shall see, in the following Book, that the true differences which exist between our globe and a perfect sphere, are known, measured, and estimated. But before setting forth this result, deduced from observations the most scientific which have been made in modern times, it is necessary to point out more precisely some of the relations which connect this earth with the other heavenly bodies, and to show, according to Lalande and Biot, in what manner these astronomical principles are connected with mathematical geography.

Irregularities of the globe.

From a simple view, we learn that the stars with which the nocturnal vault of the heavens is bespangled, appear

g *Voluspâ*, stroph. 2.

"Nio mân ek heima
"Nio *vidi*."

h Or about 6531 French metres.

i It has since been discovered, that some mountains in Tibet rise about 5000 feet higher. The accuracy of the data of this admeasurement is, however, dubious.

to move from east to west, each describing a portion of a circle. If we observe this motion more attentively, it appears to be performed about a point which alone remains immoveable: this point has received the name of *pole*, which signifies a pivot. The star which is situated nearest to this point, is called the *pole star*. The celestial vault is conceived to present itself under the appearance of a sphere; there must therefore be, in the half which is invisible to us, another immovable point: this point is the *south celestial pole*, as that which we see is the *north celestial pole*. The imaginary line which passes through these two points, and through the centre of the world, is named the *axis* of the world, from a Greek word which signifies an *axle*. This line passing through our globe forms at the same time its axis, and marks upon the surface of the earth two points corresponding to the poles of the heavens, and which are denominated *terrestrial poles*. That which answers to the pole star, is called the *north pole*, or the *arctic pole*[k]; the opposite pole is named the *south pole*, or *antarctic pole*[l]. Poles.

The point of the horizon which corresponds to the north pole, is the north, and the opposite point is the south. The circle perpendicular to the horizon, which passes through these points, and consequently also through the poles, is called by astronomers the *meridian*; it divides the visible celestial hemisphere into two equal parts; so that the stars, at the moment when they appear upon this circle, are at the middle of their apparent course; it is the passage of the sun over this same circle which determines the instant of noon. Horizon. Meridian.

We have already spoken of the *meridian line*, or of the line which joins the north point of the horizon with the south. A line perpendicular to the meridian line, and conceived to be extended both ways till it meets the horizon, marks upon this circle two opposite points, each 90

[k] From the Greek word αρκτος, *the bear*, a constellation in the neighbourhood of the north pole.

[l] From the Greek words αντι, *opposite to*, and αρκτος, *the bear*.

Cardinal points.

degrees distant from the north and south; and to which are appropriated the names of *east* and *west*.

We may illustrate these definitions upon an artificial globe, or by means of figure 1.

Illustration.

Let the circle NEMO represent the horizon, and the point A the centre, at which the observer is placed; the letters *a*, *b*, *c*, and *d*, *e*, *f*, will indicate portions of circles which the stars appear to describe about the pole. Those stars whose polar distance is not greater than the arc PN, which measures the elevation of the north pole above the horizon, appear to describe complete circles, such as S *h*, *i*, *k*; the point N marks the north point of the horizon, M the south; and consequently MN represents the meridian line. The celestial meridian is represented by the semicircle MZN, of which the plane is supposed perpendicular to that of the horizon NEMO, and which passes through the points M and N. This circle cuts at the points *c* and *e*, the arcs *a b c* and *d e f* into two equal parts. The east point of the horizon is represented by the point E, and the west by the point O: it is from E towards O that the stars appear to move, passing in the middle of their course through some point of the celestial meridian.

The true cause of these appearances, is the motion by which the earth turns round its own axis from west to east in the space of twenty-four hours. We proceed now to explain this motion by means of figure 2, which represents the globe of the earth. We shall suppose the point A to be the place of the observer, EMON his horizon, and the straight line P *p* to represent the axis round which the earth performs its motion of rotation.

It is easy to perceive, that the horizon of the observer, since it turns along with him during the rotation of the earth, must advance towards the stars successively, so as to give them the appearance of gradually approaching the horizon; in the same manner as a vessel leaving or approaching the land causes the objects on shore to appear to the eyes of an observer on board to be in motion.

As the plane MZN of the meridian turns at the same

time with the horizontal plane NEMO, to which it is perpendicular, it must point successively to the same stars, which will then appear in the middle of that part of their course which they describe above the horizon. As soon as the star touches the western verge of the horizon, that star appears to set, and ceases to be visible until the motion of the earth has brought back upon it the eastern boundary of the same circle.

This explanation gives directly a reason for the diurnal appearing and disappearing of the stars, and of the sun. But in order to conceive the use which is made of these celestial appearances in astronomy and geography, it must be observed that these motions are measured only by *angles*, without any regard to absolute length and real distances. For example, if the star π, fig. 2, appear first in the horizon in the direction of the visual ray AF, and be seen afterwards in the direction of the ray AG, the eye of the spectator measures only the angular space FAG; it determines only the arc of the circle comprehended in this angle, and not the length of the radius. This arc is estimated in degrees and parts of a degree. The circumference of every circle, whether a great circle or a small, is supposed to be divided into 360 degrees; each degree is divided into 60 minutes, and each minute is subdivided into 60 seconds. Angular measures. Degrees, &c.

It is easy to see that we may, with regard to the heavenly bodies, substitute, for the plane NEMO, which touches the earth, a parallel plane, passing through the centre. The reason is, that, when a star situated at I appears in the horizontal plane which touches the earth at the point A, an observer, placed at the centre of the earth, would see the same star upon the line CI, so that it would appear elevated only by the angle ICn, which will be so much the smaller, according as the star is more distant. The figure renders this evident with regard to the star situated at the point II. The distance of the stars being almost infinite, compared with the semidiameter of the earth, which separates the place of the observer from the centre of the globe,

this angle becomes insensible for the fixed stars, and very small for the planets.

We may substitute then without error, fig. 3, instead of the preceding figure, assuming for the horizontal plane, with regard to the stars, the plane NEMO passing through the centre of the earth, and parallel to the plane, touching it in A; or, what is the same thing, perpendicular to the radius CA, drawn from this point to the centre of the earth. We may conceive, in the same manner, the plane of the celestial meridian MZN, to be extended indefinitely around the centre C of the earth, through which it ought necessarily to pass, since it passes through the axis P *p*. This plane determines upon the surface of the earth a circle P A *p*, which passes through the poles; this circle is the terrestrial meridian of the place A, and at the same time, of all the places situated upon its circumference.

We ought to observe here, that the horizon represented by the circle NEMO, and which passes through the centre of the earth, is called the *rational horizon*, to distinguish it from the circle, which is a tangent to the surface that bounds the view, and which is called the *sensible horizon*.

Zenith. The line drawn from the centre of the globe through the place of an observer, ascertains in the heavens the position of a point Z. This point is perpendicularly over the head of the observer, and is called the *zenith*; the same line produced through the globe, marks, in the opposite part of the Nadir. heavens, another point *z*, which is called the *nadir*.

Vertical line. The position of the line ZAC, which is called the *vertical line*, is ascertained by the direction which heavy bodies take in falling, as that of the horizontal plane is indicated by the surface which water at rest and of inconsiderable extent naturally presents. The vertical line, or that which is ascertained by a thread when stretched by a plummit, is perpendicular to a like surface. This is the proper place to point out the precise situation of the antipodes. As gravity tends every where towards the interior of the globe, it acts at *a* in the direction *za* opposite to ZA; in both places bodies fall towards the surface of the earth. The people

placed at *a*, having their feet opposite to the feet of those who are at A, are called the *antipodes* of these last. The *zenith* of the one is the *nadir* of the other.

Change of the horizon.

It follows from this definition, that the horizon must change its position relatively to the stars, when the observer changes his place upon the surface of the earth. If he removes, for example, from A to *a*, fig. 4, directly along the same meridian from north to south, the horizontal visual ray NM, will become *nm*, so that a star E, situated upon the prolongation of the former ray, will appear to be elevated above the horizon, *mn* by the angle EC*m*, which is precisely equal to that formed by the radii CA, C*a* drawn to the centre of the earth; for the angles ACM and *a*C*m* being right angles, if we take from each the common angle MC*a*, it is evident that the remaining angles MC*m* and AC*a* are equal.

It was upon this principle that Posidonius, having observed that the star known by the name *Canopus*, appeared *in the horizon* at Rhodes, while it appeared at Alexandria in Egypt, elevated by the 48th part of the circle, or 7 degrees and a half, concluded that Rhodes was distant from Alexandria, in the direction of the meridian, by the 48th part of that circle. It is true that the Greek philosopher, from being ignorant that Rhodes and Alexandria are not under the same meridian, was wrong in imagining that, by this observation, he had determined the whole circumference of the earth. Still, however, his principle is true; it is the same that is employed at the present time in order to arrive at the most exact determinations: for, before measuring upon the earth the distance between any two points, it is necessary first to find, by means of observations made upon the same star, what ratio the arc A*a* of the meridian passing through the two points of observation, bears to the whole circumference.

By this observation is ascertained the relative position, with regard to north and south, of one place *a* to another A; but in order to determine in a manner more precise, the position of these places, there is required some fixed

term of comparison. For this purpose we conceive a plane to pass through the centre of the earth at right angles to the axis of rotation, and to determine upon its spherical surface a circumference GEF, fig. 5, every point in which is at the same distance from the poles P and *p*. This circle is called the *equator*. Now, if an observer be situated upon the equator, the two poles will be found exactly in the horizon; but according as he removes from this circle towards either pole, that pole to which he approaches, will rise above, while the other sinks below the horizon. Thus when he is at *a*, fig. 4, the pole P appears elevated above the horizon by the angular space PC *n*, and when he arrives at A, this angle being increased by NC *n*, becomes PCN.

Equator.

Height of the pole.

The height, or elevation of the pole above the horizon of any place, is equal to the angular distance of that place from the equator, estimated in the direction of the meridian. For the angles ACN and GCP, fig. 5, being right angles, if we take away the common angle ACP, there remains the angle ACG equal to NCP. By inspecting the same figure, we perceive that the height to which the points of the equator rise above the horizon is equal to the complement of the angle ACG.

Distances of places upon the earth from the equator.

It is sufficient, therefore, to determine for any place the height of the pole above the horizon, in order to find the angular distance of that place from the equator.

In the regions of the globe, where one of the poles appears elevated above the horizon, the stars called *circumpolar*, that is, those stars which never set, furnish directly the means of determining the height of the pole. As they appear to describe circles about the celestial pole, each must appear equally removed from it in all directions; and as they twice pass the meridian during a diurnal revolution of the earth, namely, once above the pole, and once below it, we have only to measure their angle of elevation in each of these positions, and to take the arithmetical mean between the results, in order to obtain the elevation of the pole.

By measuring, for example, at Paris, during a long winter's night, the two meridian altitudes of the pole star, we

find that, when it passes above the pole, its altitude is 50° 37′; and that when it passes below, it is 47° 4′; the sum of these being 97° 41′; the mean is about 48° 50′, which is within a few seconds of the altitude of the pole at Paris, or of the distance of that city from the equator.

Distance of places with regard to their meridians.

It is not enough to know merely the distance of a place upon the earth from the equator; because this distance is common to all the places which are situated upon a circle traced upon the surface of the globe by a plane parallel to the plane of the equator, and passing through the place in question. In order to distinguish places equally distant from the equator, it is necessary to know their meridians, the meridian being different for each place. The observation of the celestial motions may be here again successfully employed in the manner which we are now to point out. We have seen that the circles of the different meridians, PA p, PL p, PM p, &c. fig. 6, intersect each other in the axis PC p, ; but since all these meridians turn upon this line, they must also correspond successively to the same star; and the time which elapses between the passage of two meridians, containing between them any angle, will thus be to the time of the entire rotation, as the angle contained by these meridians is to the whole circumference of the circle. Hence, if we could measure the first of these intervals, in order to compare it with the second, we would be able to deduce the angle which the two proposed meridians formed with each other. To obtain this comparison, it is necessary that we should be able to indicate, by a signal visible at the same time at places under the two meridians, the moment at which a star appears upon one of these meridians, this instant must be noted, and a well regulated clock will measure the time which elapses between this passage and that of the same star over the other meridian.

When we have determined by this method the angle which the meridian PL p, passing through the place L, makes with the meridian PA p, passing through a given place A, the place L becomes entirely determined, provided that we already know its distance GL from the equator

EGF; for it will necessarily be situated at the intersection of the semicircle PL*p*, and the parallel LM, drawn at this given distance.

Definitions of latitude and longitude.

The shortest distance of a place from the equator is termed its *latitude*. This distance is measured by an arc of the meridian comprehended between the place and the equator. Latitude is north for those places which lie between the north pole and the equator, and it is south for places in the opposite hemisphere.

The angle contained by two meridians, measured by an arc of the equator, or of a circle parallel to it, is termed the *difference of longitude* of the places situated under these two meridians. That we may estimate these differences in an absolute manner, it is necessary to assume a *first meridian*, the choice of which is altogether arbitrary, and has varied at different periods. The absolute longitude of a place is therefore the angle which the meridian of that place forms with the first meridian.

We have just seen that the determination of the difference of longitude of two places upon the earth requires the use of a signal visible at the same time at both places. It is evident, that for places separated by any considerable distance, the only signals sufficiently elevated must be sought among the stars. It is indeed by means of these celestial bodies that the geographer determines the position of places. We must therefore acquire some idea of their motions, particularly of the motions of the sun and moon.

Apparent motions of the sun.

Every attentive observer of the heavens cannot but have remarked that the sun, besides its apparent diurnal motion, which it has in common with all the stars, appears, in the course of a year, to change its place in a twofold manner. First, it appears to rise and to sink alternately towards one or other of the poles, or towards the north and south. Again, if we observe its place among the stars, it appears either that the sun recedes daily towards the east, or that the stars advance in the opposite direction; for the stars which we see at any time set immediately after the sun, are, on the following evening, lost among the rays of the setting sun;

some days afterwards they re-appear in the east, and their rising precedes daily more and more that of the sun. At last, after a year, or about 365 days, the sun and stars are again seen in the same relative position.

The complexity of these motions is yet increased by the confusion presented by the apparent motions of the other planets; sometimes they seem to be hurried along by an impetuous whirlwind, at other times they appear to become stationary, or even to acquire a retrograde motion. The impossibility of reconciling this confusion of the heavens with the most simple principles of physical science, involved Ptolemy, Tycho-Brahé, and all others who, like them, maintained the doctrine of the immobility of our earth, in a labyrinth of contradictory hypotheses. Copernicus reduced this chaos into perfect order and regularity, by supposing, with some ancient philosopers, that while the earth turns upon its own axis from west to east in the interval of a day, its mass having at the same time a motion in absolute space, likewise from west to east, performs, in a plane inclined to the equator, an entire revolution round the sun in the space of a year. Hypothesis of Copernicus.

This double motion, which some minds still find it difficult to conceive, presents itself nevertheless to our view in the *top* which furnishes an amusement of childhood; at the same time that it turns, by a motion of rotation, upon the piece of iron, which, passing through it, forms its axis, it describes also upon the ground an orbit composed of curves which depend upon the impulse that it has at first received.

We proceed to the explanation of the apparent motions of the sun, according to the hypothesis of Copernicus. The axis of the earth, with regard to the plane of the ecliptic, that is, of the circle which the centre of the earth describes in its annual motion round the sun, remaining always parallel to itself, presents alternately each of its poles towards the sun. This phenomenon may easily be illustrated by fig. 7, in which the lines P *p*, which are parallel to each other, represent the axis of the earth, S the centre of the Real motion of the earth.

sun, and ABCD the elliptic curve which the earth describes about the sun. In consequence of this parallelism of the axis, the pole P, which is the one nearer to the sun when the earth is at B, becomes the more remote when the earth is at D; because in the former position the inclination of the part BP of the earth's axis is directed towards the inside of the curve ABCD; but in the latter it is directed towards the outside. At the two intermediate points, A and C, the axis PP is inclined neither towards the sun nor from it; but in every other point of the orbit ABCD, it necessarily takes an inclined position relatively to the sun. These different positions, being the cause of the difference of the seasons, deserve, however, to be explained more in detail.

Effects of the different positions of the earth.

Let us examine the position in which the pole P is directed towards the sun, and which is represented in fig. 8. A single glance shews us that the surface of the earth is at every instant divided into two parts, the one illuminated by the sun, and the other deprived of his light. The common boundary of these two parts is determined by the great circle IL *k*, whose plane is perpendicular to the line SO drawn from the centre of the sun to that of the earth. To this line we suppose the sun's rays to be parallel; seeing that from the great distance of the sun, and the small diameter of the earth, all convergency or divergency become insensible. It appears evident, therefore, that the circle IL *k*, which is denominated the *circle of illumination*, embraces the whole surface which the earth presents to the sun. Hence we see that the equator ELF, being a great circle, and consequently divided into two equal parts by the circle of illumination; each point of the equator must necessarily be illuminated by the sun during half the time that the earth requires to perform its diurnal revolution. We see besides, that all the circles described by the different points of the arc PE are unequally divided by the circle of illumination, and that this inequality becomes more sensible according as the circles are farther removed from the equator. In this case the greater of the two portions lies

upon the illuminated side of the earth; and it is only the smaller portion which lies upon the dark side: for all these points, therefore, the length of the day must exceed the length of the night. With regard to the whole region comprehended within the circle IK, described by the point I, there can be no night, since that circle lies entirely upon the illuminated side of the globe.

The other hemisphere E *p* F must necessarily present an appearance in every respect the reverse of that which we have now described. The length of the days must there diminish as we approach the pole; and the polar region, which lies entirely upon the dark side of the earth, is buried in perpetual night.

We see also, by the same figure, that while the earth revolves upon its axis, the point in which the line SHG, joining its centre with that of the sun, intersects its surface, traces upon it a circle, all the points of which come successively to receive the perpendicular rays of the sun; but if we remove from it towards either pole, we enjoy only the oblique rays. Hence it follows, the nearer a place is to the circle passing through the points G, H, the higher will the sun appear to rise above its horizon.

Position of the earth at the equinoxes.

Let us now consider the length of the days and nights at the time when the earth is situated at the point A or C. In this position the solar ray SA or SC, Fig. 7. is directed towards the centre of the earth, in a line perpendicular to the axis; and the equator, as well as all the circles parallel to it, are divided into equal parts by the circle of illumination: but since the extent of the enlightened part of the earth is equal to that of the dark part, the length of the day must therefore be equal to that of the night, for every point of the surface of the earth. The seasons at which the centre of the earth is in these two positions, have been denominated the *equinoxes;* and as the sun is then in the plane of the equator, that circle has thus received the name of the *equinoctial line*, or simply of the *line*.

Astronomical seasons.

The time which elapses during the earth's motion from the point A to the point B in figure 7, is denominated the

astronomical spring, for the hemisphere EPF. As the earth, setting out from the spring equinox, advances in its orbit, the plane of the equator becomes more and more depressed in relation to the sun, which appears to rise towards the pole. When the sun has attained its greatest apparent altitude at the point B, the semi-axis BP of the earth has then its greatest possible inclination towards the sun, which at this season appears nearest to the pole P: that day is the longest of the year, and the summer of the hemisphere EPF commences. This situation of the axis appearing to remain the same for several days, this point is called the summer solstice. This is the position which we have examined in detail in figure 8, and which corresponds to the summer of our regions. The earth having arrived at the second equinox C, autumn commences in the hemisphere which we inhabit. At this season, the sun, appearing to descend in the heavens, returns to the plane of the equator, in which he again appears to perform his diurnal revolution. Having crossed the equator, the sun still appears to descend below it, while the semi-axis CP inclines, at the same time, more and more in the opposite direction, until the earth has reached D, the point at which the winter of the hemisphere EPF commences: the axis then remaining for several days almost in the same situation, this point is named the winter solstice. The position of the earth at this point may be examined by help of figure 9, which represents the winter of our regions. The duration of this season is determined by the time which the earth employs in returning to the point A. During this period, the pole P is approaching the sun, which consequently appears to ascend towards the equator, at which it arrives when the earth, returning to the point A, finishes its annual revolution.

In the opposite hemisphere E *p* F, the succession of the seasons is reversed, so that the spring of this hemisphere answers to the autumn of the other, and so on.

We remark farther, that the orbit of the earth ABCD, Fig. 7. being an ellipse or oval, in one of the foci of which

the sun is situated, the earth employs a greater number of days in moving from the point of the spring equinox A, through the summer solstice B, to the point of the autumnal equinox C, than in describing the remaining part of its orbit. This circumstance gives to the northern hemisphere which we inhabit, the advantage of a spring and a summer a little longer than those enjoyed by the inhabitants of the southern hemisphere.

Advantages of the northern hemisphere.

The first astronomers, in order the better to estimate this apparent motion of the sun, referred it to the constellations or groups of fixed stars through which the sun appears successively to pass, and which are twelve in number. The following are their names, and the characters which are used for representing them:

The zodiac.

♈ Aries,	♉ Taurus,	♊ Gemini,	The twelve signs.
♋ Cancer,	♌ Leo,	♍ Virgo,	
♎ Libra,	♏ Scorpio,	♐ Sagittarius,	
♑ Capricornus,	♒ Aquarius,	♓ Pisces.	

These representations of animals, which astronomers, in the infancy of the science, supposed to be traced upon the heavens, led them to give the name of *Zodiac* [m] to the zone which these twelve constellations occupy. Each constellation is called a *sign*. It is proper to remark, that, in consequence of a particular slow motion of the axis of the earth, the *constellations* no longer correspond to the same points of the orbit; but, as we confine the name of *signs* to the twelve divisions of the circumference of the circle which measures the whole revolution of the earth, and as these divisions, each of which contains 30 degrees, do not change, the spring equinox always corresponds to the first point of the sign *Aries*; the summer solstice coincides with the first point of *Cancer*; the autumnal equinox falls upon the first point of *Libra*; and the winter solstice upon the first point of *Capricornus*, although the constellations or groups of stars to which these names belong, have ceased to be connected with these seasons.

[m] From ζῶδιον, an animal.

The tropics.

The apparent motion of the sun, by which he recedes from the equator, sometimes towards the north, and sometimes towards the south, causes him to pass successively through the zenith of all the points of the earth's surface, comprised between the two circles GH and *g h* (Figs. 8 and 9.) parallel to the equator, and upon which the rays of the sun fall vertically at the two solstices. These limits, at which the sun appears to stop and to retrace his steps, have received the name of *tropics*,—that is, *circles of return* [n]. That which corresponds to the summer solstice, is called the *tropic of Cancer*, and the other, the *tropic of Capricorn*.

Polar circles.

The circles IK and *i k*, which circumscribe towards each pole, the part of the earth's surface deprived of the solar rays when the sun is in the opposite hemisphere, are denominated polar circles; the one is called the *arctic*, and the other the *antarctic* polar circle.

Terrestrial zones.

The surface of the earth is thus divided into five *zones*, or *belts*, by the polar circles and the tropics: those which are enclosed by the polar circles, being deprived of the heat of the sun for a great part of the year, and during the other part, receiving its rays but very obliquely, have deservedly received the name of *frigid*, or *frozen zones*. Two other zones, one in each hemisphere comprehended between the polar circle and the tropic, receive the sun's rays less obliquely than the frozen zones, but never vertically; these are the *temperate zones*. Lastly, the zone comprehended between the two tropics, each point of which passes twice under the sun in the year, and which receives constantly the solar rays, in a direction very little oblique, has obtained the name of the *torrid zone*. We shall elsewhere recur to the physical qualities of these great regions of the globe.

Climates.

The ancient geographers frequently made use of a division of the earth into climates, which was founded upon the length of the day, compared with that of the night at

n From τροπη, a return.

the summer solstice. The climates are counted by the difference of half an hour, until we reach the polar circle, where the differences succeed each other more rapidly; from that circle to the pole they are reckoned by the month [o].

The contrast of the seasons, in the hemispheres situated to the north and to the south of the equator, has given rise to certain distinctions which it is necessary to know, as they are sometimes met with in ancient books of geography. The people who live under the same meridian, and at the same latitude, on opposite sides of the equator, are called *antœci*[p]; they reckon the same hours at the same instant, but they have opposite seasons. Those who live under opposite meridians, upon the same side of the equator, and at equal distances from it, are called *periœci*[q]: they reckon at the same instant opposite hours, the one having midnight when the other have mid-day; but lying towards the same pole, they enjoy the same seasons. Antœci. Periœci.

The ancient geographers distinguished the inhabitants of the earth likewise according to the direction of their shadows. They called *heteroscii*[r] those who inhabit the temperate zones, because their shadows, being always turned towards that pole which is elevated above their respective horizons, fall consequently in opposite directions. The inhabitants of the frozen zones, who, at one time of the year, enjoy the presence of the sun for upwards of twenty-four hours, see that luminary make a complete circuit round the heavens, so as to project their shadows in all directions; hence they have been called *periscii*[s]. Lastly, the inhabitants of the torrid zone are called *amphiscii* or *ascii*[t], because their shadows, which are almost nothing at mid-day, are directed by turns towards either pole. Heteroscii. Periscii. Amphiscii. Ascii.

[o] See, at the end of the volume, a *Table of the Climates*.

[p] From αντι, opposite to, and οικια, a habitation.

[q] From περι, about, and οικια, a habitation.

[r] From ἑτερος, different, and σκια, a shadow.

[s] From περι and σκια; see above.

[t] From αμφι, *around*, or from α, *without*, and σκια.

The right, oblique, and parallel sphere.

We pass to a distinction of more importance. In considering local phenomena, we distinguish three positions of the *sphere*, that is, of the assemblage of different circles which we have now pointed out, and which serve to determine the relative positions of the heavenly bodies.

To the inhabitants at the equator, the sphere is said to be *right*, because the plane of that circle passing through their zenith is, with regard to them, perpendicular to the horizon; and hence the heavenly bodies, which, in their apparent diurnal motion, describe parallels to the equator, appear to rise and to descend vertically in reference to the horizon. To the people who dwell between the equator and the poles, the sphere is said to be *oblique*, because the equator cutting their horizon obliquely, the apparent courses of the heavenly bodies can never be perpendicular nor parallel to their horizon. Lastly, at either pole, the horizon coincides with the equator, so that the heavenly bodies describe circles parallel to the horizon: to an inhabitant of the pole, therefore, were there any such, the sphere would appear *parallel*.

As the limits of the zones and of the climates depend upon the inclination of the axis of the earth to the plane of the ecliptic, it is of importance to determine this inclination. We may easily discover it by observing at one and the same place the greatest and least altitude of the sun, when it passes the meridian at the summer and winter solstices. For, since in both cases the sun is equally distant from the equator, on the one side and on the other, this circle must cut the meridian at a mean altitude between the extreme altitudes of the sun; and the difference of these altitudes will be double of the angular distance to which the sun recedes from the equator towards the north and south. We shall determine at once, therefore, this distance, and the position of the equator above the horizon, as soon as we have obtained the latitude of the place of observation.

At Paris, for example, the sun rises, at the summer solstice, to 64° 38′ above the horizon, and to 17° 42′, at the

winter solstice. The sum of these altitudes is 82° 20′, of which the half is 41° 10′: this is the height of the equator above the horizon of Paris; and, taking its complement to a right angle, or to 90°, we find that the distance of the equator from the zenith, or the latitude of Paris, is 48° 50′.

By subtracting the one of these altitudes of the sun from the other, we find a difference of 46° 56′, of which the half, or 23° 28′, is equal to the number of degrees to which the sun recedes from the equator towards either pole. Such is the angle which the planes of the equator and ecliptic make with each other.

This is what is called the *obliquity of the ecliptic.* It is not invariable; observations, joined with the calculation of the forces which produce the motions of the planets, have shewn that the inclination of the terrestrial equator is subject to a diminution of about 50″ in a century, till it reaches a certain limit which is not yet exactly determined, after which time it begins to increase [a]. The terrestrial zones vary therefore in proportion to this change. By assuming the mean of the present obliquity of the ecliptic, we find that if we divide the surface of the earth into 10,000 equal parts, the torrid zone will occupy 3982 of these parts, the two temperate zones, 5191, and the two frigid zones the remaining 827 parts. Obliquity of the ecliptic.

The two combined motions of the earth produce in the estimation of time a difference that influences the methods by which geographical positions are determined. We distinguish several kinds of *days* and of *years.*

The *tropical* or *solar year* is the time which the earth, setting out from one of the equinoxes, occupies in describing the ecliptic, so as to return to the same point: it comprehends 365 mean days, 5 hours, 48 minutes, 50 seconds. It is denominated the *tropical year*, because this interval of time must elapse, in order that each season may return in the same order as before. In consequence of the appa- Tropical year.

[a] Laplace, Système du Monde, p. 11 et 197.

rent motion of the poles, or of the axis of the earth, the equinoctial points, as well as all the other points of the ecliptic, appear to have a retrograde motion with regard to the stars. This motion is denominated the *precession* of the equinoxes. Astronomers have estimated it at about 50″ in a year; which lengthens the annual revolution of the earth by 20′ 24″, when it is compared with the stars.

Siderial year. The period of this revolution is named the *siderial year*, and consists of 365 days, 6 hours, 9 minutes, and 12 seconds.

Mean day. The length of the astronomical *mean* day, which is divided into twenty-four hours, is determined by the interval which elapses between two consecutive passages of the sun over the meridian of the same place, supposing this apparent motion of the sun to be performed with an uniform velocity. But it is necessary to observe, *first*, that our earth does not occupy quite 24 hours in its rotation, because that in the same time which it employs in revolving round its axis, it advances in its orbit towards the east about a degree in space, corresponding to four minutes of time, or more exactly to 3 minutes 56 seconds. Hence it follows that the interval between two passages of a fixed star over the same meridian, which measures the true time

Siderial day. of the earth's rotation, or of the *siderial day*, is only 23 hours 56′ 4″. The siderial day can scarcely be employed for measuring time in civil life, because the siderial hours never coincide with the solar hours.

Solar day. We make use therefore of the *solar day*, that is, of the time of a revolution of the earth about its axis, in reference to the sun; but this time is not the same at all the points of the orbit, or at all seasons of the year. This inequality arises from two distinct causes: the oblique position of the ecliptic with regard to the equator, and the inequality of the apparent motion of the sun in the ecliptic. The obliquity of the ecliptic causes the arc of the equator, which passes the meridian in the same time with the diurnal arc of the ecliptic, to be not always equal to it, but to be sometimes greater and sometimes less. With regard to

the second cause, we observe that the sun, being placed in one of the foci of the elliptic orbit of the earth, appears to move more slowly in the six northern signs than in the six southern; and this difference of velocity is sufficient to render unequal the diurnal arcs of the equator. It arises from the union of these two causes, that the length of the solar day, compared with the time of the earth's rotation, is sometimes less and sometimes greater than twenty-four hours; and this inequality will always be greatest when the two causes which we have just explained concur in accumulating the differences in the same direction. The series of these differences form what is called the *equation of time*, or the quantity which must, at certain seasons, be added to, and at other seasons subtracted from, the hour indicated by clocks, which are regulated by the sun, and mark the *true time*, if we wish to get the *mean* or astronomical time. Now, it is for mean time that the astronomical tables are constructed, by help of which we calculate the motions of the stars, and from these motions deduce the geographical positions of places.

Mean or astronomical time.

We have now considered the earth in relation to the sun; but it is also very closely connected with the moon. This satellite of our planet performs its revolution round the earth in 27 days 7 hours, 43′ 11″: this time is usually called a *periodical month*. It is observed, that the moon employs a little more than this time to return to the sun after each conjunction. The true cause of this difference is, that the earth, and consequently the moon its satellite, advances in the ecliptic, while the moon describes her orbit; so that before the moon comes into the same position relatively to the sun, 2 days and about 5 hours elapse, beyond the time required for completing a revolution. The whole time occupied in returning to the sun is 29 days 12 hours, 44′ 3″ 10‴. This space of time is called a *synodical month*, or lunar month. It commences from the moment when the moon is directly between the sun and the earth, in which position the moon is said to be in conjunction.

Motions of the moon.

A month.

This aspect is represented in figure 10, where S represents the sun, T the earth, and L the moon.

In describing its orbit, the moon takes, with regard to the sun, many situations, from which arise the aspects, or *phases*, which it assumes. The moon being an opaque body, can be seen only in as far as it reflects the light that it receives from the sun; it can be visible to us, therefore, only when it begins, after having passed the point L, to turn towards the earth a portion of its enlightened disk. This portion increases according as the moon recedes from the sun, until it arrives at L′, the opposite point of its orbits, when the earth being between it and the sun, we see the whole enlightened hemisphere; the moon then appears full, and is said to be in *opposition* with the sun.

The conjunction and opposition of the moon with regard to the sun, or the new and full moon, are what are called the *syzygies*. When the moon is distant from the sun a fourth part of the circumference, as at *i* or *i′*, it is in *quadrature*, and shews only one-half of its enlightened hemisphere. It is the first or last quarter, according as the round edge of the enlightened part is towards the west or east.

Eclipses of the sun and moon.

One would be led to suppose that the moon, every time it comes into conjunction with the sun, ought to conceal from us the whole, or, at least, a part of the disk of the sun; and that every time it is in opposition, it ought to pass through the shadow which the earth projects behind it; so that there would be, in the former case, an *eclipse of the sun*, and in the latter, an *eclipse of the moon*. These phenomena do not, however, occur at every new and full moon; and the reason is, that the plane of the moon's orbit is inclined to that of the ecliptic, and that these two planes meet one another only in their line of common section, which passes through the centre of the earth. It is evident that the moon is not in the plane of the ecliptic, except when it passes through one or other of the extremities of this line, that is to say, when it is in the *nodes* of its orbit. When the conjunctions and oppositions coincide with the

nodes, there are eclipses; in the opposite case no eclipse happens. We shall comprehend better these particulars by comparing figure 10, which represents in a *geometrical plane* the orbits of the earth and of the moon, with figure 11, which shows their *section* or *profile*, along the line ST. This line ST represents the plane of the ecliptic, and L *l* that of the lunar orbit. We proceed now to point out in what manner the observation of these phenomena enable us to determine the longitude of a place upon the earth.

We know, that in order to find the difference of longitude between two places, it is only required to ascertain precisely the hour which is reckoned at the same instant at each of these places, by the observation of some instantaneous phenomenon which can be seen at both.

Longitude by the eclipses of the moon.

The eclipses of the moon appear at first view the most favourable phenomena; for the entrance of the moon into the shadow of the earth takes place at the same instant for all the points of the hemisphere which is then turned towards the moon; that is, for all the places where the eclipse can be observed; besides, the spots visible upon the lunar disk, afford the means of making several observations upon the same eclipse, by marking with precision the time of the disappearing of each spot at its entrance into the shadow, or the *immersion*, and that of its reappearing at its coming out of the shadow, or the *emersion:* supposing that we have determined at each place the true time of this observation, the difference of these times, converted into degrees of the equator, will give immediately the difference of the longitudes. If all the results obtained do not exactly agree, the mean of all the observations is commonly taken; but is is much better to examine in detail the circumstances which have accompanied each observation, appreciating accordingly the relative accuracy of each, and to compare only those which are free from all suspicion of inaccuracy [x].

[x] *Burg*, in *Zach*, Astronomical correspondence, iv. 629. *Oltmanns*, Researches upon the Geography of the New Continent; *passim*.

Astronomical almanacks.

There is no absolute need of corresponding observations. The astronomical almanacks, such as the *Connaissance des Tems* of the French, the *Nautical Almanack* of the English, or the *Calendrier du Navigateur* of the Danes, give the results of the calculations of eclipses made before-hand for a known point.

It is in this manner that M. Lalande has determined the longitude of *Casbin*, a city in the north of Persia, from the eclipse of the moon which happened on the 30th June, 1787, and was observed at that place by the astronomer Beauchamp. The end of the eclipse, or the total emersion of the lunar disk from the shadow of the earth, having taken place at *Casbin* at 7 hours 45′ 30″, true time, and the calculation giving for Paris, 4 hours 36′ 38″, the difference, which is 3 hours 8′ 52″, is equal to the difference of the longitudes of Paris and *Casbin*. If we convert it into degrees, allowing 15 for an hour, which gives 15 minutes of a degree for a minute of time, and 15 seconds of a degree for a second of time, we shall have for 3 hours, 8′ 52″ in time, an arc of 45° 13′. This is the longitude of *Casbin* relatively to the meridian of Paris, as deduced from the above observation. But eclipses of the moon present this great inconvenience, that the instant when the lunar disk enters into the true shadow of the earth, the instant which marks the commencement of the eclipse, can never be assigned with precision; we cannot therefore be certain of not erring a few seconds of time in the determination of the phases of an eclipse of the moon; for this reason, the use of lunar eclipses for determining longitudes is now generally abandoned.

Longitudes by the satellites of Jupiter.

Cassini was the first who, in 1668, proposed to make use of the eclipses of the satellites of Jupiter, for the purpose of finding longitudes. The theory of these eclipses is the same with that of the eclipses of the moon; for the satellites of Jupiter, when placed in circumstances similar to those which produce the eclipses of the moon, fall, in like manner, into the shadow of their primary planet: if we observe at the same time, at several places, their immersions and

emersions, we may make the same use of these, for the determination of the longitudes, as of the eclipses of the moon. There are two other planets, Saturn and Uranus, which are also accompanied by satellites, but their smallness, and their distance, permitting them to be seen only by means of powerful telescopes, render the observation of their eclipses almost impracticable, or, at least, of little use. Even the satellites of Jupiter do not all equally well answer the purposes of the observer; for here, as in the eclipses of the moon, the precise moment of immersion and of emersion is always a little uncertain; particularly in the second and third satellites [y]. The use which may, nevertheless, be made of these satellites of Jupiter, has induced astronomers to frame tables for predicting their immersions, in order that corresponding observations may not be necessary [z].

Longitudes by the eclipses of the sun.

The eclipses of the sun are no less proper than those of the moon, for determining longitudes: it is sufficient for this purpose that we observe at each of the places of which we wish to know the difference of longitude, the commencement or the termination of one and the same eclipse; but the calculation is not so simple as in the case of a lunar eclipse. M. de Lalande, by great care and attention, has, by means of solar eclipses, corrected the positions of a great number of places. The calculation becomes more difficult, only because the relative situation of the sun and moon is not the same for the different points of the earth's surface at which these two bodies are visible at the same time. The case of the moon is the same as that of the clouds, which, seen from a particular point, appear situated under the sun, and project their shadow over a limited space, beyond which the sun shines in all its splendour. This spectacle varies continually, according as, from one instant to another, the sun, the cloud, and the spectator, change their

[y] *Rossel*, Voyage d'Entrecasteaux, ii. 245. *Zach*, Astron. Correspond. i, 421.

[z] Table of the Satellites of Jupiter, by M. *Delambre*.

situations. To employ the observation of a solar eclipse for the discovering of longitudes, it is necessary to determine several aspects of it, but particularly the beginning and the end; to deduce from thence the middle of the eclipse, and to obtain from the astronomical tables the proper *data* for fixing the respective positions of the lines described by the centre of the sun and that of the moon during the eclipse, in order that we may be able to calculate the instant when these two bodies were in conjunction. If we know then what hour at a given place corresponded to this same instant, the difference of these times indicates that of the longitudes.

The eclipses of the sun do not give the longitudes of places with much precision [a]; that of the 5th September, which was observed with the greatest care by three astronomers, exemplifies this remark. M. de Lalande deduces from it the longitude of Naples 47″ 3′ in time;—M. de *Wurm*, 47′ 40″, and M. *Triesnecker*, 47′ 20″.

Longitude by the occultation of the stars.

The celestial phenomenon which most frequently occurs, is that which is called an *occultation*, or the passage of a star behind the disk of the moon; it is, at the same time, one of those which may be observed with much precision [b]. It is necessary to determine by observation the moment when the centre of the moon is in conjunction with the star; this fixes the absolute position of the moon; next, either by means of the calculations made before hand in the astronomical almanacks which predict these phenomena, or by the comparison of corresponding observations, we must find what hour it was, at the moment of this conjunction, at a place whose position is known. The difference of longitude is then obtained as in the other methods [c].

[a] *Zach*, Correspond. i. 73. note.

[b] *Rossel*, Voyage d'Entrecasteaux, ii. 244.

[c] They who wish to become thoroughly acquainted with this subject, must consult the memoirs of geometers, among others that *Upon the Calculation of Eclipses, subject to Parallaxes*, by *M. Lagrange*, printed in German, in the Ephemerides of Berlin, for 1782, but has been published in French only, in the

It is evident that all these methods amount to this proposition, "*To determine for the place of which the longitude is sought, the position of a celestial body at a given moment, and to deduce from this position what hour it was at the same instant at another place of which the situation is known beforehand.*" Hence it follows that, without waiting for a celestial phenomenon, the change alone of angular distance between two heavenly bodies whose motion is known, should be sufficient to determine our place upon the earth. But it is also evident that the angular distance must change by the motion of one or both of the bodies with such rapidity as to present variations very considerable in the space of 24 hours. The moon alone affords us these advantages; as its motion in its orbit is at the rate of nearly 13° a day, a change of a single minute of a degree in its position, corresponds to a little less than 2′ of time, or 30′ of a degree in longitude. Now, by help of the very accurate instruments which we now possess, we can, by taking the angular distance of the moon from a star, or from the sun, ascertain with great precision the position of that body, and consequently can determine within a few seconds what hour it is, under a given meridian, at the moment of observation.

Longitudes by lunar distances.

This method, denominated that of *lunar distances*, which was first suggested in 1514 by *Werner* of Nuremberg[d], and developed in 1524 by Apian, a native of Saxony, was approved of, and recommended by various astronomers, and among others by the celebrated Kepler[e]; but the imperfection of the astronomical tables which showed the motions of the moon, rendered the practice of it uncertain. The endeavours of *Morin* to bring it into use, were not successful. Recommended anew, and better taught, in

Origin and progress of this method.

Connaissance des Tems for 1818. M. Arago observes, that there is found in it the ground work of most part of the analytical calculations that have since been published.

[d] *Werner*, notæ in Ptolom. Geog. lib. i.

[e] *Kepler*, tab. Rudolph. 37, 42.

1750, by *Tobias Mayer*, this method was employed with much success by the celebrated Danish traveller *Niebuhr*[f]; it has since been brought to great perfection by the labours of *Borda, Delambre, Burg, Maskelyne,* and more especially of *Laplace.* Ingenious instruments, constructed with the greatest care, tables calculated with astonishing accuracy, and a variety of formulas, now facilitate this operation, which has come into universal use, and, at sea, has justly superseded all the other methods.

Use of chronometers.

To lunar observations, however, is joined the use of *time-keepers,* which serve in the intervals during which observations of the distance of the moon from the sun, or from a star, cannot be obtained. These instruments would alone accomplish the end proposed, if it were possible to construct them with such accuracy, that when once regulated to the time under a given meridian, their motion would remain exactly the same during the whole continuance of the voyage[g]; for they would then at all times point out the hour under the said meridian. Even to the present time the efforts of Harrison, of Julien-le-Roi, of Berthout, of Armand, and of other celebrated artists, have not succeeded in giving to chronometers this absolute uniformity of motion; they have approached, however, so near to this perfection, that, notwithstanding the perpetual agitation of the vessel, the derangement which the rate of these clocks suffer, is insensible even during a long voyage. The imperfections to which these instruments are still liable, are, besides, remedied by observing with care the quantity which they gain or lose in a given time, and by correcting their rate when we arrive at a place of which the longitude is known.

Such are the principal methods with which astronomy furnishes the navigator and traveller, for determining the longitude and latitude of the places which they visit. We

[f] *Zach*, Astron. Corresp. iv. 246.

[g] *Fleurieu*, Voyage of Marchand, *passim.* *Dubourguet*, Traité de Navigation, book iii. ch. 10. *Rossel*, l. c. &c.

have unfolded only the general principles upon which these observations are founded; it is proper that we now take a rapid view of the errors to which these methods are subject, pointing out at the same time, the *corrections* to be applied for removing them.

Corrections of longitudes. Refraction.

The errors arising from optical illusions first present themselves to our notice. It is known that a ray of light is refracted, when it passes from a rarer into a denser medium. Hence the heavenly bodies are never seen in the true places which they occupy, the rays which enter the eye making their elevation above the horizon appear greater than the truth, by a quantity that increases according as they are nearer to the horizon. The state of the atmosphere with respect to density, influences this phenomenon. It is necessary to determine the quantity of this error for each degree of altitude above the horizon, in order that we may subtract it from the observed altitudes which are always greater than the true, except in the case of the body being in the zenith, because then the rays of light traversing the strata of the atmosphere perpendicularly, suffer no refraction.

Different physical causes, as heat, humidity, the density of the atmosphere, make refraction vary in different climates; the laws of these variations are yet unknown, and form the object of researches of importance to the improvement of astronomy [h].

Parallaxes of the planets.

We have seen above, that, on account of the smallness of the diameter of the earth, compared with the immense distance of the fixed stars, the observation of the altitudes of these bodies may always be referred to the centre of the earth, by supposing the rays of light to fall upon all the points of the earth in directions parallel to each other, and by neglecting consequently the angle AIC, Fig. 2; but this angle becomes sensible for the sun, the planets, and

[h] A. de Humboldt, Voyage, partie astronomique, i. p. 109. *sqq.* Essai sur les Refractions. Traité d'Astronomie de Biot, &c. &c.

particularly for the moon, since in neglecting it we would estimate the position of each of these objects below its real situation with regard to the centre of the earth. To render all observations capable of comparison, astronomers have agreed to consider the *true place* of a heavenly body, that in which it would be seen were it observed from the centre of the earth. On the other hand, they denominate the *apparent place* of a heavenly body, that point of the celestial sphere to which it is referred when observed from the surface of the earth. The difference in the result of these two observations will depend, as we see, upon the angle AIC, under which the chord of the terestrial arc which joins the two observers, would be seen from the centre of the heavenly body. This angle is called the *parallax*. It amounts for the sun to 8″.6, and for the moon it varies from about 54′ to 62′. The effect of parallax being contrary to that of refraction, we must add it to the observed altitude, in order to refer the altitude to the centre of the earth.

We cannot enter into a detailed explication of the corrections required by the tables which are used for calculating the observations of longitude. The celestial bodies, though they obey laws which are immutable, are yet subject in their motions to the effects of their mutual attraction, which are called *perturbations*. Hence result many small motions of acceleration, or of retardation, of which the period is sometimes more than a century, and the equations are difficult to be ascertained with exactness. The progress of the higher geometry, the theories of *De La Place*, and the calculations of Delambre, of Burg, and of other astronomers, have reduced to quantities almost insensible, the discrepancies perceived by means of corresponding observations.

Instruments.

There was, till of late years, another source of uncertainty, namely, the imperfection of instruments, which often caused the most scrupulous observers to err half a minute in the determination of an observed angle. At the present

time, not only has mechanical skill introduced great accuracy in the construction of instruments, but the ingenious invention of the *repeating circle* of Mayer, which was brought to perfection by Magellan and Borda [1], enables observers, by taking the multiple of the observed angle, to increase at pleasure the rigour with which its magnitude is determined, and to diminish the possible error almost to a second. Repeating circle.

The two methods of finding the latitude, which we have already pointed out, are not sufficient for the purpose of navigators, who, in order to calculate their longitude by lunar distances, require to know at the same instant under what latitude they are placed. This inconvenience has been in part remedied by *solar tables*, calculated before hand, and which give for every day of the year the place of the sun. The principle upon which the construction of these tables is founded, consists in presenting first the mean values of all the principal elements calculated for the beginning of the year, and then to give the means of deducing for any other instant, either the true or the mean values of these elements. In all these calculations, the first thing to be known, is the mean longitude of the sun, and of his perigee, or of his apogee, for the instant which is assumed for the commencement of the tables. These initial values are called the *epoch of the astronomical tables*. By help of these tables then, we can find the position of the sun in his orbit at any instant, and may obtain the latitude of a place, on any day, by subtracting from the altitude of the sun, his distance from the equator, if he is above that circle, or by adding it, if he is below, and then taking the complement of the result to 90°. But, in order to multiply the means of determining the latitude, astronomers, having first fixed the position of their observatory, have calculated the distance of the principal stars from the equator, and the time which elapses between their respective passages Calculation of the latitude by the altitude of the sun.

[1] Bossut, Histoire des Mathématiques, ii. 489.

over a given meridian, and that of the point of the ecliptic which corresponds to the spring equinox. The results of these calculations have been arranged in tables, by the aid of which the stars may be substituted for the sun in determining latitude.

These observations require that the position of the meridian be previously known. The pole-star indicates it nearly in the northern hemisphere of the earth; but the most universal and accurate method of finding it is afforded by the motion of the sun. Let us suppose the sun to be in one of the solstitial points; in which point it remains for some time apparently at the same distance from the equator, and appears to describe a circle parallel to the equator, whereof the part *d e f*, Fig. 1. which lies above the horizon, is divided by the meridian into two equal portions. The altitude of the sun is therefore precisely the same when observed before and after its passage over the meridian at equal intervals of time: on the other hand, if we take in the morning the altitude of the sun, and watch the moment in the afternoon when it returns to this same altitude, the hour of its passage over the meridian must necessarily lie in the middle between these two instants.

The length of shadows furnish the most simple method of determining the altitude of the sun. It is easy to see that this length depends not only upon the height of the objects by which the shadows are projected, but also upon that of the sun, relatively to the plane upon which the objects stand. If upon this horizontal plane we raise the vertical line AD, Fig. 12. the solar ray being directed along SD, the shadow will fall upon AC, and its length will depend upon the angle SCA, which evidently corresponds to the height of the sun above the horizon. When the sun, after having passed the meridian, returns therefore to the same altitude on the other side, and in the direction S′D, the shadow AB and the vertical line AD will be again of the same length with the shadow AC; and if we take the middle position of the shadow between the direction of the

one and of the other, by dividing the angle BAC into two equal parts, by the straight line AN, we shall find the meridian. If the length of the staff AC is now measured, and that of its shadow, we shall be able to find the altitude of the sun, by the resolution of the rectilineal triangle CAD, which is rectangular at A, and in which the sides AD and AC are known, so that we may calculate the angle ACD, which is the altitude sought. The meridian altitude will be obtained, if we measure the length of the shadow when it falls in the direction of AN. It was by such means that the first astronomers determined the altitudes of the heavenly bodies. This rude instrument is called a *Gnomon;* but it has been abandoned since the instruments which measure angles immediately by arcs of the circle, have been brought to perfection. These last are employed even in determining the meridian, by combining them with pendulum clocks, of which the motion is very regular. Having observed in the morning an altitude of the sun, we mark at the same time the hour, then we watch the instant in the afternoon when the sun is at the same altitude, and taking half the interval, we find the time which has elapsed between the passage of the sun over the meridian, and either of the observations. Gnomon.

If, for example, the clock indicate for the same altitude, in the morning $8^h\ 45'\ 30''$, and in the afternoon $3^h\ 23'\ 12''$; the interval between these two instants is $6^h\ 37'\ 42''$, of which the half is $3^h\ 18'\ 51''$, and this added to the time of the first observation, namely $8^h\ 45'\ 30''$, gives $12^h\ 4'\ 21''$, for the hour which the clock must have indicated at the instant when the sun passed the meridian. The observation of these *corresponding altitudes*, many times repeated, serves to regulate the clock, and to ascertain exactly the moment of the sun's passage over the meridian, whence the direction of the meridian line may be immediately determined.

The observation of equal altitudes may be employed at every other season of the year, as well as at the solstice, by applying to the result a small correction for the change which the sun's declination undergoes in the interval be-

tween the two altitudes, and which causes the length of that interval to vary. A great many circumstances influence this kind of observations, and renders them more or less subject to error, particularly when made on shipboard. The details must be sought for in works which treat professedly of these subjects [k].

The position of the heavenly bodies relatively to the meridian, and their bearings from the north and south, and east and west points of the horizon, inasmuch as the former serves to ascertain the true hour, and the latter to fix the true north and south points, contribute to facilitate or to verify, the operations by which we determine the position of places upon the earth.

Horary angle. The *horary angle* of a heavenly body, is the angle which is formed at the pole, at the instant of observation, between the meridian of the place of the observer, and the circle of declination or hour circle, passing through the body. This last circle is nothing else than the meridian of the body. The horary angle is measured by the arc of the equator which has passed, or will pass, under the meridian of the observer, between the instant of observation, and the moment when the heavenly body is upon this same meridian.

Azimuth. The *azimuth* of a body, is the arc of the horizon intercepted between the south point, and that in which a vertical circle passing through the zenith and the body, cuts the horizon.

Amplitude. *Amplitude* is the arc of the horizon intercepted between the point where the body rises or sets, and the true east or west point. The former is called *eastern* amplitude, the latter *western* amplitude. The horary angle, the azimuth, and the amplitude, contribute in several ways to the determination of longitudes and latitudes; the first serves to ascertain the true hour, by only one observation of the altitude of the sun, and so gives the means of regulating the chronometer [l]; the other two indicate to the navigator how

[k] Levéque, Guide du Navigateur. Dubourguet, Traité de Navigation.

[l] Rossel, Voyage d'Entrecasteaux, ii. 27, *sqq.*

much the magnetic needle deviates from the true north and south line; they teach also the method of placing a geographical map due east and west [m]. Upon these relations of the heavenly bodies to the meridian and horizon, are likewise founded various subsidiary methods for calculating by approximation the latitude of a ship at sea [n]; but as these methods, though ingenious, are very subject to error, and are seldom used in geography, we shall not stop to describe them.

Use of signals made by gunpowder.

To all these methods which the observation and calculation of the celestial motions furnish, for determining geographical positions, is now added the use of signals made by gunpowder. In a very elevated place, during a serene night, a quantity of powder is from time to time inflamed in the open air; two observers, each provided with a clock, and stationed at the places of which the difference of longitude is required, mark with care the appearance of these flashes,—an appearance which, notwithstanding the distances, is instantaneous at the two places, in consequence of the prodigious velocity of light. The difference of the times indicated by the two clocks, will give the difference of longitude sought [o].

Let us conclude this sketch, which is necessarily dry, of the methods by which longitudes and latitudes are determined, with observing to those of our readers who have no taste for such matters, that the exact knowledge of positions is the ground-work of all geography; and that without this knowledge, the most splendid description would only possess a merit altogether illusory.

[m] Puissant, Traité de Géodésie, p. 300, *sqq.*

[n] Mendoza, Connaiss. des Temps, 1793, p. 289, 302. Dubourguet, Traité de Navigation, b. iii. chap. 3, 4.

[o] Puissant, Géodésie, p. 299. Zach. Astron. Corresp. M. Schumacher, Professor of Astronomy at Copenhagen, has lately brought this method to singular perfection. In the measurement of the arc of the meridian, and of the perpendicular to that arc, which is committed to his superintendance by the King of Denmark, he has made use only of a luminous signal.

BOOK II.

Continuation of the Theory of Geography. Dimensions of the Globe determined. Its oblate figure. Basis of the new metrical System.

Principles of the measurement of the earth.

THE active curiosity of man did not rest contented with having demonstrated that the earth is a moving sphere; but proceeded to ascertain the exact dimensions of the planet which had been assigned to him in the immensity of space. An arc of the celestial meridian being measured, it was natural to conclude, that as this arc ought to correspond to a similar meridional arc on the surface of the earth, it would be necessary only to measure this latter curve, in order to find the dimensions of the entire circle, and consequently of the circumference of the globe.

Measures of the ancients.

We have already seen the wide difference of the apparent results of the different measures of the earth, undertaken by Eudoxus, Archimedes, Possidonius, and Erastosthenes [a]; we have pointed out the method of reconciling those measures, by referring them to different *stadia*; but we shall not at present enter on a formal discussion of the very intricate question whether those operations have been actually executed by the persons to whom they are ascribed, or if the Greeks have merely availed themselves of the science of a more ancient people, and taken credit for discoveries which they did not fully comprehend. In our opinion, the *stadium* being a measure of local and real distance, and not merely an astronomical modulus, it is probable that we are indebted to the Egyptians and Babylonians for the computations of the circumference of the earth, in *stadia* of 1111 and 833 to a degree, whilst the results found by using stadia of 700 to a degree, and other hypo-

[a] The author here refers to the *History* of Geography, the Part first published in French, but which is to be the last of this translation.

theses, may be very well considered as the work of Erastosthenes, Possidonius, and other Greek astronomers.

It was observed, in the foregoing book, that Possidonius committed an error in taking for an arc of the terrestrial meridian that which connected Alexandria and Rhodes, since those places, which were the points of comparison, have not the same longitude. If we except this error, the method of Possidonius was the true one. Erastosthenes made use of a *gnomon* placed vertically in the centre of a concave sphere[b]; he knew that at *Syene*, the sun, at the time of the solstice, projected no shadow; he remarked that at Alexandria, the gnomon, at the same instant, projected its shadow over the fiftieth part of a circle; he hence concluded the latitude of Alexandria to be 7° 12′ north of Syene, which must have been situated under the tropic. But according to the moderns, the latitude of Syene is 24° 5′, consequently that of Alexandria would be 31° 17′, which is not far from the truth. However carefully this observation was made, the Greek astronomer could not adopt it as a solid basis for the measurement of the earth, as the two points which he compared are not situated under the same meridian.

Gnomon of Erastosthenes.

The measures of a degree, attributed to the Arabians, exhibit in like manner equivocal results, and which cannot be reconciled with the truth but by means of arbitrary computations.

After the revival of letters, the European astronomers made many fruitless attempts to measure accurately a degree of the meridian[c]. In 1617, *Snellius*, after having determined the celestial arcs, comprised between Alkmaer, Leyden, and Bergen-op-Zoom, by the difference of the altitudes of the pole in those three places, calculated the terrestrial meridional distances of the three parallels, by means

Measures of Snellius, Norwood, &c.

[b] Cleomed, Meteor. I.

[c] Fernel, about the year 1530, divined with sufficient exactness, by a very imperfect method, the value of a degree between Paris and Amiens, which he computed to be 57070 toises. This wonderful coincidence has not yet been explained.

of a series of triangles connected together, and the base whereof was actually measured; he thus found that the value of a degree of the meridian was 55,021 toises, or 58,639 English fathoms, of six feet each. *Norwood*, an English astronomer, in 1635, measured with the utmost care a degree of the meridian between London and York; he found the degree to be 57,310 toises, or 61,078 fathoms, which result is a very near approximation. However, fifteen years afterwards, *Riccioli*, a celebrated Italian astronomer, pretended to have found by a measurement carried on in the environs of Bologna, that a degree of the meridian was 62,900 toises, or 67,036 fathoms; but this result is far from exact, as there is an excess of almost 6000 toises, or 6395 fathoms above the real value.

Picard's measurement.

It was by applying the telescope to instruments used in the taking of angles, that *Picard*, of the Academy of Sciences of Paris, was enabled to carry on with the necessary precision, the new measure of a degree which he commenced in 1669. He chose for the theatre of his operations, the space contained between *Sourdon* in Picardy, and *Malvoisine*, on the borders of Gâtinais and Hurepoix[d]. In order to ascertain the itinerary distance which separates those two points, situate under the same meridian, he connected them by a series of triangles, Fig. 13; he observed successively all their angles, which furnished him for each a method of verification, as the sum of the angles of every triangle, is constantly equal to 180°. He scarce ever obtained this sum; but the inevitable errors amounted only to a few seconds.

Trigonometrical operations.

A triangle is indeterminate, if only the angles be given, and we can obtain no more than the ratio of the sides; but one side being known, the rest are easily found. Picard therefore measured with a precision till then unknown, a distance of 5663 toises, or 6035 fathoms, on the road of Villejuif, at Ferney. With this base, represented by AB, in the triangle ABC, he calculated the side AC; and with this he

[d] Picard, Mesure de la Terre, 161.

found CD, in the triangle ACD[e]; and thus he proceeded from triangle to triangle, as far as Sourdon. Here again was measured a right line RS, as a *base of verification*. The line LM, IN, IG, verified by means of this base, gave only a difference of one or two toises from the first measure. New triangles were afterwards carried on, as far as the Cathedral of Amiens, where the operation ended.

It was then necessary to find the length of the line which joins those points, and its position with respect to the meridian of Paris, in order to ascertain the distance in the direction of this meridian; and also to determine accurately the amplitude of the arc measured on this circle, that is, how many degrees and parts of a degree it contained, in order to deduce its ratio to the whole circumference.

Astronomical operations.

In this second part of his operation, which depended on the observation of the stars, he attached himself to that which is placed in the knee of the constellation of Cassiopea. He preferred this star, because not being far distant from the zenith, it was less affected by refraction, which in his time was attended with much doubt. By this means he found that the difference of latitude between Malvoisine and Sourdon, near Amiens, was 1° 11′ 57″; that it corresponded in the direction of the meridian, to a distance of 58,480 toises, or 62,272 fathoms; and hence he concluded the length of the degree to be 57,064 toises, or 60,816 fathoms.

He found also, between the cathedral of Amiens and Malvoisine, a difference in latitude of 1° 23′ 55″, and a distance of 78,850 toises, or 85,034 fathoms, which gave for the degree 57,057 toises, or 60,808 fathoms; he chose the mean of both these results—57,060 toises, or 60,812 fathoms.

Dimensions of the earth.

The circumference of the earth, like every other circle, is divided into 360 degrees; and by dividing a degree into

[e] Short example of the calculation:—In the first triangles it was found by observation that CAB=54°, 4′ 35″, ABC=95°, 6′, 55″, ACB=3°, 48′, 30″. By measurement AB was found to contain 5663 toises; therefore by the rule of proportion we find AC=10,012 toises, 5 feet, and so on.

twenty parts, called *sea leagues*, each of which is equal to 2864 toises, or 3052 fathoms, it will be found that the circumference contains 7200 of those leagues.

Its diameter, deduced from the circumference, is 2292 sea leagues, and its radius, or a right line drawn from the centre to the surface is 1146. Multiplying the circumference by the diameter, we find that the surface contains 16,502,400 square leagues.

Experiment of the Pendulum.

The accuracy of Picard's operation, seemed to remove all doubt respecting the dimensions of the earth, when the important experiments made by M. Richer at Cayenne in 1672, shewed that the figure of the earth was not perfectly spherical, and that consequently the degrees were not equal. His pendulum clock, regulated at Paris by the mean motion of the sun, after being transported to the island of Cayenne, which is only about 5 degrees from the equator, was found to lose every day 2 minutes, 28 seconds. The length of a pendulum, which at Cayenne beat seconds exactly, being marked upon an iron bar, which was brought to France, it was observed that the pendulum of Cayenne was $1\frac{1}{4}$ line shorter than that of Paris, which measured 3f. $8\frac{5}{9}$lin. or, more exactly, 440,57 lines [f], or 39,156 English inches.

This experiment proved that the force of gravity was less at Cayenne than at Paris; for when the pendulum which regulates the clock, deviates by its motion from the vertical position, the force which attracts it thither is gravity; and the interval of time it takes to return to that situation, is so much shorter, if the power of gravity augments, and so much longer if it diminishes. The index cannot point to a second, till after the pendulum has completed an oscillation, or after one fall in the vertical. Thus, if during a revolution of the stars, the index does not mark a sufficient number of seconds, the pendulum employs more time to regain its vertical situation and gravity, the power which impells it, is diminished.

[f] A line is the twelfth part of a French inch.

This experiment, the importance of which was foreseen by the Academy of Sciences g, perfectly coincided with the reasoning of mathematicians, who began to consider the earth as depressed towards the poles; and the cause of the augmentation of gravity, or the attracting force, was explained by the depression of the surface, which therefore approaches nearer to the centre.

Huyghens, a Dutch mathematician, had the glory of divining that truth, even before the experiment of the pendulum was known. Considering that bodies which revolve round a centre, or an axis, acquire a *centrifugal force*, which tends constantly to make them fly off from this centre or axis, as we observe in a stone whirled about in a sling, he concluded, that the fluid diffused over a considerable part of the surface of the earth, could not assume a form perfectly spherical, as it must be affected at the same time by the force of gravity impelling it towards the centre. He supposed, therefore, that the earth must be depressed towards the poles, and that the axis of rotation was shorter than the equatorial diameters by $\frac{1}{578}$, which is equal to about four sea leagues. This consequence, deduced from the centrifugal force by Huyghens, may be made sensible to the eye, by turning rapidly a wet bladder round an axis, which then assumes the form of a spheroid flattened towards the extremities, contiguous to the axis. Huyghens's theory.

The immortal Newton, who, by profound reflection on the laws of the planetary motions ascertained by Kepler, discovered the principle of universal gravitation, no longer considered gravity at the surface of the earth as a constant force, everywhere directed towards the centre of our globe, but as the result of the mutual attractions of all the particles of the earth to each other; he found that this force varied a little in intensity and direction, from the earth not being perfectly spherical. If the figure of the earth depended upon gravity, gravity would regulate itself according to the Newton's Theory.

g Lalande, Abrégé d'Astronomie, art. 742 and 805.

figure which the earth had; this accelerating force, as to terrestrial bodies, ought to be perpendicular to the surface, and proportional to the distance; the earth having once assumed the oblate figure, this figure alone, independently of the centrifugal force, ought to render gravity weaker under the equator than under the poles. Newton, calculating on this principle, and supposing the earth homogeneous in all its parts, found, for the quantity of depression, $\frac{1}{230}$, or 10 sea leagues[h].

Investigations of Maclaurin, Clairaut, &c.

Those conclusions, differing as to the quantity of the result, but agreeing with respect to the alteration which the figure of the earth ought to undergo in consequence of the centrifugal force, have been developed by the most delicate and profound calculations. Of these we can only here point out the results[i]. It has been demonstrated, that the earth could not be a homogeneous mass, but that its density ought to increase in descending to the centre; and that, in all cases, an elliptical figure satisfies the laws of the equilibrium of fluids.

At the same time, the theory of the diminution of gravity towards the equator, was confirmed by a great number of observations on the pendulum, from Lapland to the Cape of Good Hope[k]; and from their general agreement it has been concluded, that the depression of the globe is equal to the 332nd or 336th part of its axis[l].

Inequality of the degree on the oblate plane.

The theory of the depression of the earth might also be verified by measures taken on the terrestrial globe; for it results from this theory, that the degrees of latitude cannot be equal throughout the whole extent of the meridian,

[h] Newton Principia, b. iii. prop. 19.

[i] Clairaut, Theorie de la Figure de la Terre. Maclaurin, Memoir on the Flux and Reflux of the Sea. D'Alembert, Recherches sur le Système du Monde, &c.

[k] Dubourguet, Traité de Navigation, note i. page 290, 291. Histoire de l'Acad. des Sciences, passim.

[l] Laplace, Système du Monde, p. 250. Svanberg, Exposition de la Mésure d'un Degré.

but that they ought to be augmented, in the flattened part of the meridian, that is, towards the poles, and diminished in the convex part of the same meridian, or near the equator. Those consequences, which flow from the fundamental notions of elementary geometry, were however for some time mistaken by men of very great merit, such as Cassini, and d'Anville. It may not therefore be improper to insist a little on the demonstration.

A degree of the meridian is the portion A*a*, Fig. 14, of that curve, when the radii CA, C*a*, which intercept that part of the arc, form an angle AC*a*, equal to the 360th of the circle. In consequence of this definition, it is easy to perceive that the radii CA, C *a* perpendicular to the tangents, will meet at the same distance in the curve only when this curve is a circle; that to the same arc will correspond the same angle, and that in this case the degrees throughout the whole extent of the curve will be of the same length. But this does not apply to curves whose curvature is not uniform. In the ellipse, for example, if we take two arcs of the same length, as M*m*, and N*n*, Fig. 15, one in the most concave part, and the other in the flattest part of the figure, the perpendicular M*c*, *mc*, drawn to the extremities of the former arc, will meet nearer in this arc, than the perpendiculars NC, *nc* drawn to the extremities of the other arc. The angle N*cn* is therefore visibly less than the angle MC*m*, and consequently if the latter be equal to one degree, the arc N*n*, equal in length to M*m*, does not correspond to a degree. To obtain this angle in the part NP of the curve, it is necessary to take in a space greater than M*m*. Therefore the terrestrial degrees must be greater in the flat part of the globe, if we would have them correspond to the celestial degrees which are all equal, not being real arcs, but only angular distances.

We may also reason in the following manner:—The point where two verticals meet, is the centre of the terrestrial arc contained between them; if this arc were a right line, the verticals would be parallel, or would meet only

at an infinite distance. The greater the curvature of the arc, the more the verticals converge, therefore they meet at a less distance. Thus the part of an ellipse near its great arc being the most curved, the verticals which are perpendicular to it, will meet at a smaller distance. The radius of the arc intercepted between them will be shorter, and consequently, the absolute length of the arc itself will be less. On the contrary, near the small arc, the verticals meet at a greater distance, showing that the radius of the intercepted arc, and the arc itself, are longer.

Paralogism on this subject.

By not tracing those notions to their source, the contrary was concluded at the commencement of the last century, because it was supposed that the degrees were determined by the angles M *om*, N *om*, formed by the lines drawn to the centre of the ellipse EPQ*p*; but this hypothesis was not conformable to the principles of the operation, for the lines OM and O *m*, ON and O *n*, not being perpendicular to the curve, differ entirely, both in magnitude and direction, from the verticals to which are referred the points of the celestial arc.

The measures of Cassini having seemed at first to indicate a diminution of the degrees from south to north, several learned Frenchmen maintained, by means of the paralogism above cited, that this diminution was a proof of the depression at the poles; the mathematicians demonstrated that it was rather a proof of the contrary. The error of the principle was at length discovered, and it has not been since revived but by entire strangers to geometry [m]. But Cassini and D'Anville, in deducing from the pretended diminution of the degrees towards the north, the natural conclusion, affirmed that the earth swelled out in its polar direction; or, in other words, that the terrestrial ellipsoid performed its revolution round its major axis; which was contrary to the theory of gravity and the equilibrium of fluids.

[m] Bernardin de St. Pierre, Etudes de la Nature, &c.

In France, the notion prevailed for forty years, that the earth is a spheroid protracted towards the poles [n]. At length, the Academy of Sciences resolved to ascertain the truth of the theoretical conclusions on the subject, and selected from their own body two companies of mathematicians, who were dispatched, the one in 1736 to Peru, and the other in 1737 to the polar circle, to measure a degree of the meridian in the regions bordering on the equator and the pole. The results obtained by these companies, compared with each other, and with the degree measured in France by Picard, though they did not entirely agree with respect to the quantity of the depression of the earth at the poles, yet they completely dissipated all doubts of the fact [o]. The degree measured at the polar circle exceeded that of the equator by 659 toises, or 703 fathoms; and the French degree, though smaller than that of the polar circle, still surpassed that of the equator by 307 toises, or 327 fathoms. Measurement carried on in Lapland and Peru.

The Cassinis themselves, after having verified their measures, had the candour to avow that they had fallen into some slight errors, and that the degrees measured by them in France concurred to prove the depression of the globe towards the poles [p].

It was not enough that the science of mathematicians had described, in a general way, the figure of our globe, they further endeavoured to discover the exact quantity of that depression, the existence of which had been proved by so many experiments. But, in this investigation, the accumulation of the materials only increased the difficulty of the question. The degrees successively measured in different parts of the world gave very different quantities for the depression. This was demonstrated with great perspicuity by an Italian mathematician, by comparing the twelve best measures known for half a century back [q]. We shall first Different other measures.

[n] Bossut, Hist. des Mathématiques, p. 273.

[o] Bouguer, Figure de la Terre. Maupertuis, Elémens de Geographie, &c.

[p] Cassini et de Thury, Meridienne de l'Observatoire royale verifié, 1744.

[q] Pauli Frisi, Cosmographia, tom. ii. Chap. de Figura Planet. comp. id. Opera omnia, t. iii. p. 123, 599.

give the results of those measures, with the names of the astronomers to whom we are indebted for them:

Names of the Countries.	Latitude whence the measurement commenced.	Value of the degree measured.	Names of the Observers.
Peru . .	0d 0m	56,753 tois.	Bouguer, La Condamine, &c.
Cape of Good Hope	33 18	57,107	Lacaille.
Pennsylvania	39 12	56,888	Mason and Dixon.
Ecclesiastical State	43 1	56,979	Boscovich and Maire.
France .	43 31	57,048	Cassini and Lacaille.
Piedmont .	44 44	57,137	Beccaria.
France . .	45 45	57,050	Cassini and Lacaille.
Hungary .	45 57	56,881	Liesganig.
Austria .	48 43	57,086	Idem.
France .	49 23	57,074	Picard and Cassini.
Holland . .	52 4	57,145	De Thury and G. Cassini.
Lapland . .	66 20	57,405	Maupertuis, &c.

Note. One toise is equal to 1.06575 English fathoms.

Frisi endeavoured to calculate a regular curve according to Newton's theory, which might correspond to those twelve degrees, but he found them either too great or too small; the errors which should be supposed in the measurement in order to reduce them to a regular ellipse, whose minor axis would be to the major in the ratio of 230 to 231, amounted to more than 100 toises, or 106½ fathoms the degree, and for the degree of Hungary to more than 200 toises, or 213 fathoms.

These measures compared by Frisi.

Frisi also endeavoured to find, by binary and decimal combinations, a mean term between the different depressions pointed out by the measures; but as a severe criticism of the accuracy of each measure did not precede his combinations, we shall not here cite any of the results; we shall only observe that, by choosing, among his binary combinations, the six in which we can have confidence, we find for the mean term a depression almost identical with that furnished by the observations of the pendulum and the late French measures. Here is the comparison:

The difference of the axes, or the absolute value of the depression, being taken for unity, the first degree combined with the third, gives for the major axis of the earth 505 si-

milar parts; with the fourth, 353; with the seventh, 292,3; with the ninth, 290,4; with the tenth, 307,4; and with the eleventh, 270. Therefore the mean term of the depression is equal to $\frac{1}{316}$.

The acknowledged impossibility of finding one regular curve which would correspond with the different degrees measured, produced different opinions among philosophers. The operation of M. Maupertuis in Lapland was first condemned as uncertain, either on account of the negligence with which it was conducted, or because the arc measured was not of sufficient extent, or, lastly, on account of the doubts which this mathematician himself had entertained with respect to the result of his measurement [r]. The same judgment should be passed on the measure of Father Liesganig, executed with very inaccurate instruments, and wherein it is now demonstrated [s] that there is a confusion of two stars nine degrees distant from each other, and other constant errors from 10 to 12 seconds, which correspond to 150 toises, or 160 fathoms; consequently this measurement does not deserve to be taken into consideration. Not being aware of this error in the operation of Liesganig, some very excellent mathematicians have given themselves the useless trouble of attempting to reconcile the irregularity of the degrees of Austria and Hungary with the general theory [t]. Errors in those errors.

The measures which might be safely relied on, took in but a small portion of the globe. Neither Frisi nor the other philosophers who have written on this subject, were acquainted with the degree measured in the year 1702, in China, in the 40th degree of latitude, by the Jesuit Thomas, the value of which degree was found to be 56,987.899 toises, or 60735 fathoms of six feet each; which, by supposing a depression of $\frac{1}{314}$, would differ on

[r] He makes the degree in his Figure of the Earth, 57,405, and in the Elements of Geography, 57,438.

[s] Zach. Astron. Correspond. viii. 507. *et seq.*

[t] Dubourguet, Traité de Navig. p. 283, 308, &c.

ly 23,983 toises, or 26 fathoms, in excess from the value presumed. But this measurement being susceptible of several interpretations, there can be no great harm in neglecting it[u].

Errors caused by *attraction.*

Some persons have been tempted to doubt of the possibility of measuring a degree of the meridian with perfect accuracy. The errors inseparable from the nature of the instruments then employed, might amount to 3 or 4 seconds for the celestial arc, or 60 toises for the terrestrial degree[v]. *The attraction* of mountains, which deranged the plumb line by which the *vertical* is determined, excited the most restless doubts. This effect of gravitation, a striking proof of Newton's general theory, might affect measurements in other respects executed with the greatest care, since a deviation of the vertical line, of 15 seconds only, at both extremities of the arc measured, would cause an error of 500 toises, or 533 fathoms, which quantity is greater than the presumed difference of the two extreme degrees under the equator and the pole. But Newton had estimated this attraction at two minutes, for a mountain three English miles in height and six broad. This estimate, it is true, has appeared excessive. By the observations which Bouguer and La Condamine carefully made in 1737, in Peru, near the mountain of Chimborazo, the plumb-line deviated $7\frac{5}{10}$ seconds in consequence of the attractive force of that mountain, which, according to Newton's theory, should have produced an effect 13 times greater; but the nature of the volcanic rocks of that mountain renders the experiment dubious[w]. Similar effects have been observed in the Pyrenees, the Alps, the Appennine mountains, and in Scotland, where Maskelyne repeated those observations with the utmost precision,

[u] Hallerstein, Obser. Astr. Pekini Sinarum factæ, p. 366. Vindob. 1768. Comp. Zach. Ast. Corresp. i. 248, 251, 589, 594.

[v] D'Alembert, Encyclopedie, *Fig. de la Terre.* Bouguer, Fig. de la Terre, Sect. 1. § 4. &c.

[w] Bouguer, Fig. de la Terre.

and obtained a result which approaches nearer to Newton's theory[x]. It is very possible that this attraction may have affected the measures taken by Lacaille, since that astronomer performed no experiment to determine the effect of the mountains of the southern part of Africa, on the plumb-line of the instrument which he made use of.

Opinion concerning the irregularity of the meridians.

At length, a simple and decisive idea presented itself to the mind of some superior geniuses, who were fatigued with the interminable dispute of the earth's depression. It was supposed *that the curvature of the terrestrial spheroid might be subject to some slight irregularities.* Why should nature, which is not fond of geometrical figures, have made the earth a perfect and regular ellipsoid? Buffon was one of the first who proposed this opinion[y]; Condamine seems to have favoured it[z]; and Maupertuis, who at first had loudly rejected it, at last only doubted of it[a]: Lacaille, whose measures did not agree with any other, naturally inclined to an explication which justified his operations. However, natural philosophers in general still objected to this opinion, which was feebly supported by those who had advanced it.

M. Klügel's hypothesis.

A more serious attempt to maintain the regular ellipsoid, was made by M. Klügel, a German mathematician. To demonstrate that all the degrees accurately measured, even that of Lacaille, might be applied to a regular ellipse, he supposed a small difference existed between the *minor primitive axis of the terrestrial ellipsoid*, P*p* Fig. 16, and *the actual axis of rotation* $\Pi\pi$; whence would result for example, that the Cape of Good Hope, might have been originally nearer to the south pole, or, more accurately speaking, that the southern extremity of the axis of rotation has changed its position with respect to the equator *Eq.* Therefore the southern degree *a b*, although more distant from the pole of rotation π than the northern degree from

[x] Philosophical Transactions, 1775, p. 500.

[y] Nat. Hist. tom. i. p. 165.

[z] Rapport sur les Mesures du Pérou, p. 262.

[a] Lettres Physiques.

the pole Π, might nevertheless be in the same situation with respect to the true minor axis of the ellipsoid Pp; and would consequently have the same absolute value, notwithstanding the difference of latitude[b]. It is obvious what revolutions would take place on the earth, if this hypothesis had any foundation. It is evident that the major axis of the globe would no more coincide with the plane of the equator; and is it possible, according to the laws of hydrostatics, that the terrestrial ellipsoid could perform its revolution round any other axis than its real minor axis? But, whatever objections may be made to M. Klügel, his hypothesis appears so ingenious, and would be so fruitful in interesting results for physical geography, that we thought proper to give an idea of it here.

Such were the doubts of astronomers and mathematicians respecting the figure of the earth, when a political project afforded an opportunity for undertaking a new measure of the arc of the meridian, which, passing through the capital, traverses France. The National Convention ordered that a uniform and permanent system of weights and measures should be established. The philosophers proposed to found the basis of this system upon nature, and to *take as the primitive unity* of *measure*, or *metre*, the *ten millionth part of a quadrant of the terrestrial meridian*, that is, the space between the equator and the pole. It was said that a metrology founded on such a basis would belong to every age and nation. But how were they to find precisely the length of the fourth part of the meridian? They could not deduce it from the ancient measures, for these contradicted each other; it was therefore determined that the new metrological system should be rendered more authentic by founding upon new operations, conducted with a precision till then unknown, and directed by the most able astronomers. Delambre and Mechain were appointed to measure the arc of the meridian intercepted between the

Measurement conducted by Delambre, Mechain, Biot, &c.

[b] Klügel, Dimensions de la Terre, &c. in the Astronomical Collections of Berlin, iii. 164, 169.

parallels of Barcelona and Dunkirk. These two celebrated geometricians measured the angles of 90 triangles with the new repeating circles which Borda had constructed; they observed with these instruments, 5 latitudes at Dunkirk, Paris, Evaux, Carcassonne, and Barcelona. The two *bases* near Melun and Perpignàn were measured with platina and copper rules, and were found to agree, to a few inches, with the measures calculated. Minute attention prevented or rectified the smallest errors. The most eminent of the French mathematicians, together with a number of others sent from different countries, verified and sanctioned all the calculations. No farther doubt, therefore, can be entertained respecting the results of this vast enterprise, which commenced in 1792, and terminated, as to the measurement, in 1798.

Results.

It has been proved, that the degrees of the meridian diminish towards the south, and increase towards the north. But this augmentation of the terrestrial degrees does not follow a regular and constant progression. Therefore no meridian whatever can be a regular ellipse. It is probable, that the earth itself is not a *solid of revolution*, that is, circumscribed by the revolution of an individual ellipse round its centre. However, those irregularities which appear extremely small in comparison with the mass of the earth, may, without inconvenience, be overlooked.

Quantity of the depression.

The meridian of France, which Messrs. Biot and Arago have lately prolonged, by a very tedious operation, as far as the isles of Ivica and Fromentera [c] gives, if we consider it apart [d], for the quantity of the depression $\frac{1}{150}$, and, by comparing it with the degree of Peru, it would give $\frac{1}{311}$.

Accords with phenomena.

This latter result, adopted by the commission of weights and measures, coincides with what was found by observing the pendulum. It agrees also with several celestial phenomena, the cause whereof is the non-sphericity of the earth; for this planet being swelled towards the equator, the attraction of the sun and moon

[c] Notice of the operations carried on in Spain. Mercury, Jan. 7, 1810.

[d] Laplace, Système du Monde, p. 62.

is there more powerful than towards the poles; and, as the plane of the equator is inclined to the ecliptic and lunar orbit, this additional attraction communicates to the axis a progressive motion, which causes the equinoctial points to retrograde, and an alternate motion, by which it oscillates around the position it would have by virtue of the first motion. The latter is called the *precession of the equinoxes*, and the former the *nutation*. M. Burg, a celebrated German astronomer, having calculated, at the request of M. de Laplace[e], the causes of those perturbations, and the influence of the earth's depression, found the latter to be $\frac{1}{305}$.

New measurement by the Swedish astronomers.

The degree measured at the polar circle by the French academicians in 1737, was that which differed the most from the general result deduced from all the other data. We have already mentioned, that considerable errors were suspected in the operation, and this has been since demonstrated. M. Melanderhielm, a learned Swedish astronomer, undertook to get a new degree measured by M. Svanberg, one of his pupils, and for that purpose the repeating circle was employed, and all the delicate methods of modern *geodesia*. The French academicians had measured only an arc of 57′, but M. Svanberg extended the operation to 1° 37′. By the definitive result of this measure[f], a degree of the meridian is found to be 57,209 toises, or 60,970 fathoms, in latitude 66° 20′, or 196 toises, shorter than that which was measured in 1737. This, compared with the French degree, gives for the depression $\frac{1}{301}$, and with that of Peru $\frac{1}{334}$. We may also, by different hypotheses, combine this measure with a depression of $\frac{1}{310}$. Thus there is no essential difference between this result and that which was adopted by the French mathematicians[g].

Accords with the French measure.

[e] Laplace, Système du Monde, p 218.

[f] Svanberg, Exposition of the Operations carried on in Lapland. Stockholm, 1805, p. 161, 92.

[g] Since the publication of this work, the king of Denmark, full of zeal for the progress of the sciences, has ordered an arc of the meridian to be measured which passes through Jutland, Fionia, Holstein, and Lauenbourg, and which contains 4 degrees of latitude. This measurement it entrusted to one of the ablest modern astronomers, M. Schumacher of Copenhagen. At the same time,

Observations made on the planets, which are several millions of leagues distant from us, have concurred to establish our ideas respecting the oblate figure of the terrestrial spheroid. The alteration of the spherical figure, resulting from the rotation of a celestial body on its own axis, appears also in the planet Jupiter, where it is so sensible that the difference of both diameters of the disc may be discerned by means of a telescope. This difference is almost $\frac{1}{10}$th; and when we compare the exact measure of this depression, the dimensions of Jupiter, and the time of his rotation with those of the earth [h], we find for this latter planet a flatness proportional to $\frac{1}{178}$; which still coincides with the grand French measure. Depression of Jupiter.

It must not be dissembled, that this accord, which apparently ought to have been universal, was affected by some new doubts suggested by two German mathematicians, by reason of the geodesical operations of the English. The two measurements in the East Indies, the one by *Burrow*, under the tropic, the other by *Lambton* at 12° north latitude, have furnished results which combine tolerably well with those of the French measures, though they are still more favourable to Newton's theory [i]. But the measure of 3 degrees by Major Mudge [k] in England, gives, according to the German mathematicians, considered by itself, a depression under *the equator* of $\frac{1}{3}\frac{1}{3}$th. This singular result seems to prove decidedly, that the spheroidal figure of the English measures. Doubts.

the celebrated M. Gauss of Gottingen, is directed to measure an arc of the meridian of 3 degrees in Hanover. This operation will likely be connected with that of the Danes.

It is known that, since the publication of this volume in 1812, (second edition,) the English and French mathematicians have connected together the grand and magnificent geodesical operations of France and England.

By these measures, the curvature of the earth is exactly determined from the Shetland islands to the island of Fromentera. See the *Notice* published by M. Biot.—*Author's note.*

[h] Laplace, Système du Monde, 253.

[i] Zach. Corresp. xii. 488—493.

[k] Phil. Trans. 1803, part ii. p. 383. Comp. Lindenau in Zach. Corresp. xiv. 137, *et seq.*

earth is subject to irregularities which can only be determined by multiplied measurements [l].

Geographical conclusions.

We may therefore consider the quantity of the earth's depression as sufficiently determined for geographical purposes. There are few geographers indeed, who, in the construction of maps on a small scale, have paid attention to the depression or ellipticity of the earth. Maupertuis, Murdoch, and others, have indeed calculated tables, which give the increase of the degrees of longitude on an elliptic spheroid [m]. The geographer Bonne demonstrated to Rizzi Zannoni [n], that in his large map of Europe, he ought to have made allowance for the effect of ellipticity, which was then presumed to be $\frac{1}{179}$. But the measures and calculations have now changed one of the elements of this question. The depression of the earth, reduced to the $\frac{1}{334}$ of the equatorial diameter, not producing between this diameter and that which passes through the poles more than a difference of about 7 leagues, would give for a spheroid, the major axis of which would be 3 feet, a difference of only $1\frac{1}{3}$ line, or about $\frac{1}{8}$th of an inch, a quantity which it would be extremely difficult to observe with precision in the construction of globes. They may therefore be made perfectly spherical. In topography and special hydrography the effect of ellipticity is perceptible not only in the degrees of latitude, but also in those of longitude; it is the duty of a careful geographer to attend to it, by following the methods which several late works give for express-

[l] Laplace, Mecan. Céleste, ii. 144. Since the publication of this work, few memoirs have appeared on this subject, at least to our knowledge: but the opinion, supported by so many physical probabilities, that the earth is composed of two unequal hemispheres, seems to have been rejected by Laplace. *Note of the Author.*—Much light will be thrown on this subject by the labours of Mudge, Colby, Kater, Macculloch, &c. who have been employed lately in extending the British arc of the meridian to Shetland, combining it with the French arc, and determining the length of the pendulum at different points.

[m] Maupertuis, Elem. de Géograph. Comp. Mem. de l'Acad. des Sciences, 1711, p. 466.

[n] Refutation of a work of M. Rizzi Zannoni, entitled, Dissertation on different points of Geography, by M. Bonne, a rare work, communicated by M. de Lalande to M de Zach. Corresp. i. 186.

ing those differences[o]. The tables annexed to this volume give all the necessary details for ascertaining the absolute value of each degree of longitude and latitude, as also for the comparison of the new metrical system with the ancient measures. However, we cannot terminate this short historical account of the investigations relative to the figure of the globe, without placing before the reader the principal results of the great French measure.

Basis of the New Metrology.

	In Metres.	In French Feet.
The fourth part of the meridian	10,000,000	30784440
The Decimal degree	100,000	307844,4
Myriametre	10,000	30784,44
[p] Kilometre	1,000	3078,444
Hectometre	100	307,8444
Decametre	10	30,78444
Metre	1	3,078444

New Astronomical Divisions.

The fourth of the meridian	100°		
Degree		100′	
Minute or prime			100″
Second			100‴

Compared with the ancient Astronomical Measures.

1 Centesimal degree equal to	54°
1 Minute	32″4
1 Second	0″324

Dimensions of the Globe.

	In Metres.	In Toises.
Radius of the equator or semi-major axis of the terrestrial ellipsoid	6,375,750	3,271,226
Radius of the semi-minor axis	6,356,662	3,261,432
Depression at the poles, or excess of the equatorial above the polar radius	19,088	9,794
Radius of the earth supposed to be spherical	6,366,206	3,266,329
Circumference of the ellipsoid under the meridian of Paris	39,999,867	20,522,960
Circumference under the equator	40,059,948	20,553,717

Note. The French metre is 39.371 English inches; the toise, according to General Roy, is 1.0657 English fathoms.

[o] Puissant, Traité de Géodésie, p. 125, *et seq.* Dubourguet, Traité de Nav.

[p] The name adopted is *Kilometre*; but it is a barbarism: the proper expression is *Kiliometre*.

Principal Degrees.

	In Metres.	In Toises
Ancient degree of Latitude under the equator	110,614	56,753
Ancient degree of latitude at 45° N. latitude	111,117	57,011
Ancient degree of latitude at the pole	111,612	57,264
New degree of latitude under the equator	97,552	51,078
New degree of latitude at 50° N. (new meas.)	100,006	51,310
New degree of latitude at the pole	100,449	51,538

	On a Sphere.	On a Spheroid with a depression of $\frac{1}{313}$
New degree of longitude at 0° of latitude	100,000m	100,149m
Id. at 50° N. latitude (new div.)	70,711	70,922
Id. at 99° latitude	1,571	1,577

The minuteness of those differences by which our terrestrial ellipsoid has been proved to deviate from a perfect globe, strikingly exhibits the accuracy and nicety of the methods employed by astronomers and mathematicians. What delicate instruments must have been used, what rigorous calculations made, in order to determine, within a few toises of the truth, the dimensions of this vast globe, in comparison of which our body is but an atom! Let not this discovery at least be attributed to the ancients! If some learned men have pretended to see clearly, in some vague phrases of the ancients, a notion of the polar depression [q], there are others who have as clearly discovered the idea of an equatorial depression [r]; those two opposite opinions, therefore, destroy each other. The notion even of the ellipticity of the terrestrial globe could not arise but from a clear idea of universal gravitation. It was therefore reserved for the genius of modern geometry to draw the human mind into this bold and subtle research.

Whether the ancients were acquainted with the depression of the globe.

q Freret, Mem. de l'Acad. des Inscriptions, tom. xviii. p. 112.

r Burnet, Theoria Telluris Sacra, p. 26, 136, 137.

BOOK III.

Continuation of the Theory of Geography. Of Terrestrial Globes. Of their Construction and principal Uses[a].

To fix well in the mind the different parts of knowledge which form the study of geography, it is necessary to have before our eyes an image of the earth and its parts, on a small scale. The most simple of these representations is the *artificial terrestrial globe;* it is the earth in relief, with its seas, continents, and islands. The mountains, rivers, and principal towns, are also indicated on it. All these points have on the artificial globe their *true position;* they are represented in their totality, and relatively to each other, as they are situate on the earth itself, according to astronomical observations and geodesic measures. A geographical map can only give perspective views of a part of the globe, in which there are always more or less of errors of convention.

Description of the artificial globe.

We find in the artificial globe the material image of those mathematical circles which serve to give us an idea of the various relations of the earth with the heavenly bodies, and of terrestrial places with each other. Thus, on the surface of the globe ought to be indicated, the terrestrial equator, the tropics, the polar circles; then, by weaker lines, the other parallels to the equator, from 5 to 5, or from 10 to 10 degrees, according to the size of the globe. We also find the meridians indicated from 5 to 5 or from 10 to 10; they are numbered at their point of intersection with the equator. The parallels to the equator are also numbered at the place where they cut that meridian which has been chosen for the first. The ecliptic is also marked on good globes.

[a] Bion, Usage des Globes, 1718. *Schiebel*, Instruction sur l'usages des Globes Artificiels (en Allemand) 1779 & 1785.

The poles are indicated by two points, on the axis of which the globe turns. These two points are fixed to a circle of metal which surrounds the globe from one pole to the other, so that on turning the globe, every terrestrial spot passes under this circle. It serves, therefore, as a *general meridian*, and is so called. The degrees of latitude, and even, on large globes, the minutes and seconds, are marked on the general meridian.

The bearers, or feet of the whole machine, support a circular band of metal or wood; it cuts the globe, in whatever position it may be placed, into two hemispheres, one superior, the other inferior; and thus represents the rational *horizon*. This artificial horizon has several circles traced on its surface; the inmost marks the number of degrees of the twelve signs of the zodiac; on it are the names of those signs and the days of the month. Another circle is divided into thirty-two parts, which mark the points of the compass.

The quadrant for taking heights is intended as a substitute for the compass in different researches. It is a little plate of copper attached to the general meridian, and divided into 90 degrees [b], which serves to measure the distance and position of the places without the compass. The *horary circle* is fixed on the north pole; it is divided into 24 hours, and bears a moveable needle, which turns round the axis of the globe. There is also at the foot of the globe a *compass*, which should be fixed in the parallel and meridian of the horizon.

Rules to choose a globe.

Globe-makers, and especially those of Paris, have been so careless of late years, in the delicate construction of that instrument, that a lover of geography cannot be too scrupulous in examining the quality of a globe before he purchases it. He should ascertain the complete correspondence of the divisions marked on the circles. The degrees of the equator and the ecliptic should be equal with each other and with those of the quadrant. The same equality

[b] It commonly goes to 114 degrees, or to the arch equal to the diameter.

should exist between the degrees of the general meridian and the horizon, represented by the interior circle of the circular band of the middle. These divisions are examined, by intercepting with a compass a certain number of degrees, and by trying if, with the same opening of the compass, the same number of degrees can be intercepted every where. The globe should be at an equal distance from the general meridian and from the horizon, and far enough from them never to rub against those circles; which only happens in the very worst globes. The globe should be balanced perpendicularly on the two points which represent the poles. This is known, if, when turned, it stops as soon as the hand is taken from it. The equator should, in all positions, cut the meridian, and, if there be one, the horizon, into two equal arches; it ought therefore always, on turning with the globe, to coincide with the points where the quarter of those circles begin. In the parallel sphere, it should always preserve the most exact parallelism with the horizon. In like manner, the tropics and polar circles should every where coincide with the latitudes that belong to them.

The network, or assemblage of the lines representing the circles of longitude and latitude, should correspond exactly in all its joinings; which is very seldom the case even in large globes; the surface of the paper pasted on the globe being rarely connected with perfect exactness.

Construction of the globe.

The globe serves, generally speaking, to recapitulate the elements of mathematical geography. In order to shew its use, we shall now explain its primitive construction. The most simple and most exact way of constructing a globe is to draw immediately on its surface, by the means we are about to describe, the circles, lines, and points, which it ought to represent c.

Let us suppose that two points diametrically opposite, have been fixed to represent the poles, and that the axis of rotation is to pass through them: taking one of these points

c Varenius, General Geography, b. iii. chap. 32. prop. 5.

for a centre, at an equal distance from each, a circle must be described, which will be the equator; another great circle will be drawn through the poles to represent the *first meridian*, which will be divided into 90 degrees, setting out from the equator towards each pole: afterwards, setting out from this meridian, the circumference of the equator must be divided from degree to degree. These two circles being determined, it is easy to mark on the globe a place, the latitude and longitude of which may be learnt from the geographical tables; for it will be sufficient to mark the former on the first meridian, and through the point where it falls, must be described, taking the pole for the centre, the circle parallel to the equator, passing through the proposed spot; then drawing through the point of the equator on which the longitude falls, and through the poles, a semicircle, the meridian will be had, whose junction with the parallel marks the position of the place.

It is thus that the *circles of latitude* and of *longitude* are traced on the globe, at the distance of 10 or 5 degrees from each other. With respect to these circles, the following remark may be perhaps a little too elementary for most of our readers.

Decrease of the degrees of parallels.

The *circles of latitude* are parallel to the equator; they diminish therefore necessarily till the last circle of latitude is identified with the point of the pole itself. The *circles of longitude*, or the *meridians*, go from pole to pole, and cut the equator perpendicularly; they are equal, with a very slight difference. The degrees of latitude are counted only on the circles of longitude, and *vice versâ*. The *degrees of latitude* are, therefore, little arches of $\frac{1}{360}$ of a *circle of longitude*, intercepted by two *circles of latitude*. They would of course be equal without this small difference, which proceeds from the depression, and makes them increase a little towards the poles. The *degrees of longitude* are little arches of $\frac{1}{360}$ of a *circle of latitude*, intercepted by two *circles of longitude*. Therefore the degrees of longitude go on diminishing in proportion as the circles of longitude come near each other; and at the point where

all these circles, till then convergent, cut each other, that is, at the pole there is no more longitude.

The reckoning of the latitudes begins at the equator. This commencement is naturally determined by the circumstances of the earth's motion. It is otherwise with the longitude; for all the meridians being great circles, nature furnishes no motive for choosing one in preference to any other, as a term from which to begin to count, or as *first meridian*. We need not be surprised, therefore, that geographers have varied much in their choice. First meridian.

Ptolemy fixed his first meridian at the Fortunate Isles, (now the Canaries,) because it was the most western limit of the countries known in his time; and as their extent from east to west was more considerable than from south to north, the former received the name of *longitude*, or length, the latter that of *latitude*, or breadth, which they still bear. This first meridian of the ancients is not known with certainty, as its position depends on the precise meaning of the appellation *Fortunate Isles*, a point which we shall discuss in the history of geography.

In order to render the manner of expressing longitudes in French geography uniform, Louis XIII. ordered, by an express declaration, that the first meridian should be placed in the *Isle of Ferro*, the most western of the Canaries. Delisle, one of the first who endeavoured to give precision to geographical determinations, fixed the longitude of Paris 20 degrees east of that meridian. When, by more rigorous observations, it was known that the difference of longitude between Paris and the principal town of the Isle of Ferro was 20° 5′ 50″, it was necessary to advance the first meridian 5′ 50″ to the east of that point, so that it is now a circle of mere convention, which passes through no remarkable point.

The Dutch had fixed their first meridian at the Peak of Teneriffe, a mountain situated in the island of that name, and then esteemed the highest in the world.

Gerard Mercator, a famous geographer of the 16th century, chose the meridian which passes through the island

Del Corvo, one of the Azores, because in his time it was the line on which the magnetic needle suffered no variation. It must be confessed, that it is the most natural and the most commodious point of departure with respect to maps of the world.

Geographers have only agreed together in maintaining an abuse, that is in understanding by the name of the meridian of a place, only the half of the great circle corresponding with the celestial meridian; the other half, which is in the opposite hemisphere, with respect to the poles, is sometimes called the *anti-meridian*.

Meridian and anti-meridian.

According to the custom of geographers, the longitudes begin to be counted from the eastern side of the first meridian, and are reckoned in the same direction over the whole circumference of the equator, till they return to the western side of the meridian. In this way of counting the longitudes may rise to 360°.

Longitudes counted after the custom of navigators.

These conventional arrangements have not been adopted by mariners. Astronomical observations having become of general use in navigation, and the tables which indicate the moment of the celestial phenomena, and the position of the heavenly bodies at different epochs, being always calculated for the meridian of the principal observatory of each nation, navigators found it more convenient to refer to this meridian the points of the routes they followed. Thus French mariners count from the meridian of the observatory of Paris; the English from Greenwich; the Spaniards from Cadiz. Let us observe, moreover, that mariners estimate the longitude from the difference of the time which elapses between the passage of the meridians through the same heavenly body, or from the difference of hours counted at the same moment in two different places. If one has advanced towards the east, one counts more than under the meridian from which one set out; the contrary happens when one advances towards the west. It is necessary, therefore, when we convert a difference of time into a difference of longitude, to indicate if it be *oriental* or *occidental*. In this way of counting, the longitude is always marked by the side near-

est the first meridian, so that the longitudes only embrace the semi-circumference, or do not rise beyond 180°: and the globe is divided into two hemispheres with respect to the first meridian; in the hemisphere situated to the west, the longitudes have the denomination of *occidental;* and in the other *oriental.* All marine charts are established according to this system of numeration.

Reduction of geographical longitudes.

These diversities in the manner of estimating the longitude necessitate calculations of reduction. We are obliged, before using a map, to examine what is the meridian adopted by the geographer, "which often embarrasses even learned persons[d]."

When we have to do with longitudes reckoned according to the method of geographers, that is, by making the entire tour of the globe by the east, we must take the difference of longitude of the two meridians to be compared; and if the meridian from which we wish to set out is to the west of the other, this difference must be added to all the longitudes counted from the other; in the contrary case it must be retrenched.

For example, Moscow is 35° 12′ 45″ from the meridian of Paris, how many is it from that of Greenwich? Add the difference, which is 2° 20′ 15″, and you will have the result 37° 33′. Here is another: Paris is 20° from the meridian of the Isle of Ferro, how many is it from the Dutch meridian of Teneriffe? This meridian being a degree more to the east than the other, retrench 1° from the given longitude, and you will have 19°. In this calculation there happen two particular cases. The result by addition may surpass 360°; for example, Madrid is 353° 57′ 40″ from Paris, counting in the manner of geographers, how many from the Isle of Ferro? You find, on adding the difference of the meridians, 373° 57′ 40″; but as this sum exceeds the value of the whole circle, you see you have repassed a second time through the meridian of the Isle of Ferro. You must, therefore, retrench 360°, and you have

[d] D'Alembert, dans l'Encyclopedie.

13° 57′ 40″. In the same way it sometimes happens, that the given longitude is less than the difference of the meridians to be retrenched from it; in this case 360° are added to the longitude, the difference is then retrenched, and the sum required is found. For example, the isle Gomere is 32′ from the Isle of Ferro, you ask how much it is from the meridian of Teneriffe? Add 360° to 32′, retrench the difference, and you have 359° 32′, which is the longitude required. The reason of these operations is perceived on repeating them on the globe.

Reduction of nautical longitudes.

The reduction of longitudes, reckoned according to the practice of navigators, is much more in use. In setting out from the same meridian, all the oriental marine longitudes, as far as 180°, remain the same as in the manner of reckoning adopted by geographers. With respect to the occidental marine longitudes, it is sufficient to deduct them from 360°, to bring them to the numeration of geographers. Here is an example: Venus's Point, in the island of Otaheite, has been determined by navigators to be 151° 50′ 30″ of western longitude from the meridian of Paris. If from 360° we take off 151° 50′ 30″, the difference, which is 208° 9′ 30″, will be the longitude according to geographers. It is evident that, by an inverse operation, we may transform into nautical longitude the geographical longitudes above 180°, by deducting them from 360°.

If we set off from two different meridians, we must observe on what side the meridian to which we wish to refer the longitudes is placed with respect to the other. We must retrench their difference from all the longitudes of the same denomination as that side, and we must add to all those of a contrary denomination. An example will make this rule more easy. The meridian of the observatory of Paris being 2° 20′ 15″ to the east of that of Greenwich, all oriental longitudes with respect to Greenwich must be diminished by that quantity to be referred to the meridian of Paris, and the occidental longitudes must be augmented by that quantity. It is thus that the longitude of the Cape of Good Hope being 18° 23′ 15″ to the east of the meridian of Greenwich, becomes 16° 3′ to the east

of that of Paris; on the contrary, Cape Horn, placed by the English at 67° 21′ 15″ west of Greenwich, is 69° 41′ 30″ west of Paris.

In these reductions, as in those of the geographical longitudes, it may happen that the points to be reduced fall between two meridians, or between their opposite meridians. The place which is oriental with respect to one, then becomes occidental with respect to the other. In the first case, we can no longer retrench from the longitude to reduce the difference of the two proposed meridians; we must do the contrary, and change the denomination. In the second case, the number which results from the addition of the difference of the meridians, to the longitude wanted from the meridian we wish to change, surpasses 180°, because it is beyond the meridian opposed to that to which the longitudes are referred; it must, therefore, be retrenched from 360°, or from the entire circumference, to make it go off from a side contrary to the same meridian; the longitude consequently changes its denomination again.

Dover, for example, is 1° 18′ 39″ to the east of Greenwich. Subtracting this longitude from the difference of the meridians 2° 20′ 15″, there will remain 1° 1′ 45″, which is the *occidental* longitude of Dover with respect to the meridian of Paris. Here is an example of the second case: At Turtle Isle, situated in the Pacific Ocean, the English count 177° 57′ west longitude. Adding to this 2° 20′, we find 180° 17′. The place is, therefore, 17′ beyond the meridian opposed to that of Paris; and by retrenching 180° 17′ from 360°, we have 179° 43′ of east longitude with respect to the meridian of Paris.

When the principal circles of longitude have been traced on the globe, and places known by observations have been marked on it, which are generally the capitals of states, the most frequented ports, and most salient promontories, it only remains to fill up the intermediate spaces, by drawing from the best geographical maps the sinuosities of shores, the course of rivers, and the chains of mountains. But as all the materials of these designs must be taken from maps, of which we shall explain the construction in the

following Books, it would be premature to treat here more at length of the rules to be observed in choosing the best, and in transferring them to the globe with the greatest exactness. We shall only remark, that the method of delineating geographical outlines immediately on a ball of copper, wood, or any other matter, is only employed by lovers of the science who wish to join instruction with amusement, or by geographers who are particularly employed by some great nobleman. The globe-makers use a method less tedious, less expensive, which allows them to multiply copies. They have a general map of the world drawn and engraven, and distributed into slips, that is, spherical segments, with which they cover the ball destined for a terrestrial globe. The way of tracing these slips will be indicated in its place.

Common way of making globes.

Uses of the globe.

Distance of places.

The first use that is made of the globe, is to determine the distance from one place to another. The shortest distance of two points on the sphere, is measured by the arc of the great circle which joins them; and as all great circles are equal, the degrees of any one of them contain the same number of itinerary measures as those of the meridian. We take therefore with a compass the opening of the arc comprised between the points proposed, and carry it to the meridian or the equator, which are graduated.

If, for example, the arc comprised between two places marked on the globe, and brought to the meridian, contain 10° 45′, we shall have the shortest distance between these points in itinerary measures, by converting the degrees and minutes into marine leagues of 20 to a degree. We first obtain 200 leagues for the 10°, and each minute being equivalent to a third of a league, or a *nautical mile*, the 45′ will give 15 leagues: thus the total result will be 215 marine leagues.

In delicate operations, however, it is better to use calculation, which gives a more precise result. Let us consider, for example, the spherical triangle APL, Fig. 6, formed by the meridians AP and PL of the places A

and L, whose distance we require, and by the arc of the great circle AL, which joins them. In this triangle we know the sides AP and PL, which are the distances of the points A and L from the pole P, or the complement of their latitudes, and the angle APL, which is measured by their difference of longitude; the rules of spherical trigonometry will give us, in degrees and parts of degrees, the side AL, which we can convert into itinerary measures. In the case where the places A and L are in different hemispheres, one of their distances from the pole will be greater by 90° than the latitude of the place itself[e].

If the places of which we wish to know the distance have the same meridian, it is only necessary to take the difference of their latitudes, and to convert it into itinerary measures. A difference of some minutes in longitude has no sensible effect on the result; thus, we should hardly mistake more than a league in measuring the distance from

[e] Some of our readers will be pleased, perhaps, with an example of this sort of calculation.

The distance from Paris to Philadelphia is required. Longitude of Philadelphia, 77° 36′ 0″ W. Long. of Paris, 0° 0′ 0″. Difference of Long. A = 77° 36′ 0″. Lat. N. of Paris, 48° 50′ 15″; therefore the complement B = 41° 9′ 45″. Lat. N. of Philadelphia, 39° 56′ 57″; therefore the complement C = 50° 3′ 3″. Multiply the *tangent* B by the *cosine* A, you will have a tangent which we shall call x. It must be subtracted from C if A is below 90°, and added if A is above. There results the quantity we shall call y. Now, as th cosine x is to the cosine B, so the cosine y is to the cosine of the distance required D. The calculation is made by means of the Tables of Sines.

Log. tang. B = 9.94165
Log. cos. A = 9.33190

Log. tang. x = 9.27365
Therefore x = 10° 37′ 48″
C = 50° 3′ 3″

C − x = y = 39° 25′ 15″

Log. cos. x = 9.99249
Log. cos. B = 9.87670
Log. cos. y = 9.88790

Log. cos. D = 9.77211
therefore D = 53° 42′ 50″
= 1074 leagues, 20 to a degree.

See the trigonometry, and the general formulas in Puissant, Traité de Geodesie, art. 89. Comp. art. 30.

Paris to Algiers on the meridian of Paris, though it is 41′ more to the west than that of Algiers.

Remarks on the measures of distances.

It would be a great error to take the difference of longitude in *degrees* of two places, situated on the same parallel, for the measure of their distance; this can only be done when the places are situated on the equator, which is a great circle; but its parallels being small circles, the radius of which diminishes as we approach the poles, it follows from the principle stated above, that the absolute length of their arcs does not give the true measure of the shortest distance from the extremities of those arcs; this distance can only be measured by a great circle passing through the two extreme points. For as the radius of the parallel is shorter than that of the great circle, the arc of the parallel must necessarily have a greater curvature than that of the great circle comprised between the same points, and is consequently longer. Here is a striking example: Petersburgh is almost under the same latitude as the isle of Kediak, in Russian America; the difference of longitude is about 180°, equivalent under this parallel to 1800 marine leagues; but the shortest distance between these two places is, counting on a meridian that is almost common to them, 60 degrees of latitude, equivalent to 1200 leagues. It is true that, to take advantage of this, it would be necessary to cross the eternal ice of the pole. Thus, in geography as in politics, the straight road is not always the most advantageous.

Law of the decrease of the degrees of longitude.

It is necessary, therefore, in many cases, to measure the distances on the parallels, and, consequently, to know exactly the value of the degrees of longitude marked on the parallel circles. The globe renders the diminution of these degrees towards the poles sensible to the eye; our tables indicate it in detail[t]: But we should know the mathematical principles of it. The length of the degrees marked on the parallels is proportionate to the radii of the circles; but the radii of the equator, and of its parallels, are per-

[t] See the *Tables* annexed to this volume.

pendiculars let fall from the different points of the meridian on the diameter of each of these circles, as in Fig. 6. the lines EC and HK. Consequently, if we take the radius EC for the length of the degree of the equator, and if we divide it into twenty parts, representing marine leagues, the number of these parts which the radius HK of the parallel LM may contain, will indicate the value of the degree of this parallel in leagues. Hence it results, that, to determine the length of the degrees on each parallel, we have only to describe on a line EC, which represents the length of the degree of the meridian, or of the equator, a quarter of a circle EP, divide it into degrees, and let perpendiculars fall from each point of division on the radius CP; these lines will mark the respective lengths of the degree of the parallel for each latitude.

As the line HK is the sine of the arc PH, and the cosine of the arc EH, one of which indicates the distance from the parallel HM to the pole, and the other the latitude of that parallel, it is evident that, taking for unity the degree of the equator, that of any parallel whatever will be the cosine of the latitude given by the trigonometrical tables. For example, the latitude of Paris is 48° 50′, and the cosine of this angle 0.658 of the radius; multiplying this number by 20 marine leagues, we have for the value of the degree of the parallel 13 leagues $\frac{6}{10}$. In the latitude of Petersburgh, or 60°, the degree of longitude is reduced to 10 leagues, because the cosine of 60° is the half of the radius.

Relation of places to the points of the horizon.

We have mentioned what is to be understood by *north* and *south*, *east* and *west*; it is by studying the globe attentively that we come to understand perfectly the value of those terms. Two terrestrial points, situated under the same meridian, are directly north and south of each other, and all the intermediate points, that is to say, all the points of the line of distance, are equally north and south of each other, and all reciprocally on the same point of the compass. In like manner, any two points whatever, taken under the terrestrial equator, are directly east and west of each other,

and all the intermediate points are equally so, and are reciprocally on the same point of the compass.

If we take two places which are neither under the same meridian, nor under the equator, whatever be otherwise their relative position, none of the intermediate places will be, with respect to the other places, on the same point of the compass. For the arc of a great circle which measures the distances, is an arc of a vertical circle which passes by the zenith of the two places in question; but every vertical circle which is itself neither a meridian, nor perpendicular to the terrestrial meridian, (like the equator,) will cut all the intermediate meridians under angles unequal among each other. But it is these angles of position which determine the point of the compass on which a place is relatively to another. Therefore, as all the intermediate places between the two places in question will offer angles of position unequal in degrees, each of them will be on another point of the following place from what the preceding place was from it. Thus, in following the shortest route, between two places situated out of the equator, and under different meridians, the point of the compass would change at every step. This is demonstrated by Fig. 17, where PEp represents a meridian, EGIi the equator, HLQ a parallel, and HIKi the great circle perpendicular to the meridian in H. We perceive, also, that all the great circles perpendicular to the same meridian, meet in two opposite points I and i, which are the poles of that meridian. These great circles must, therefore, continually approach each other; and it is only in a very small space, on each side of the meridian PEp, that the circles IEi and IHi can be considered as parallel with each other; and hence, too, it can only be in a small extent that the lines *east* and *west*, or the perpendiculars to the meridian, can be considered as parallel[g].

Lines east and west.

As the great circle IHK, perpendicular to the meridian p'EP, cuts the other meridians under angles different for

[g] See afterwards *Projection of the Maps of Cassini.*

each, while the parallel HLQ meets them all at a right angle, it is evident that, in going from the point H to the point L on the parallel, we turn off every moment from the direction we at first followed, to place ourselves at a right angle with the different meridians we cut, and which all unite at the pole P. We cannot, therefore, trace on the terrestrial surface a parallel to the equator, or advance directly either *east* or *west*, but by means of a compass, or still more exactly, by determining the meridian from place to place, and keeping one's self always in the same latitude.

This difference between the points *east* and *west* of the globe, and those of each place in particular, has an influence on navigation and on maritime charts. The navigator endeavours, as much as possible, to sail on the same point of the compass, at least for a certain time, otherwise he cannot know where he directs his course. Moreover, he must first direct his course so as to reach the spot he wishes to go to; and secondly, he should go by the shortest way possible. If a vessel sails always east and west under the equator, its route will be an arch of the equator, and consequently the shortest road between two places situated under the equator. If a vessel be directed constantly north or south, it will describe an arc of the meridian, and at the same time the shortest road between the place of departure and that of arrival. If a vessel, out of the equator, sails constantly east or west, it will describe a parallel to the equator. Therefore, if the place of its destination is to the east or west of that of departure, and under the same parallel, the vessel would arrive there indeed, by sailing always on the same point of the compass, but sometimes by a very tedious course. Navigator's route.

If, on the contrary, a vessel is directed constantly towards the same point of the compass, that point not being one of the four cardinal points, it will describe on the globe *a curve, which does not return into itself, but which is indefinitely prolonged in a spiral manner, always approaching the pole, without ever reaching it.* The *loxodromic line* Loxodromic line.

may be also defined to be, a species of logarithmic spiral, described on the surface of the sphere, having the meridians for its radii.

This line was discovered by Nonnius, a Portuguese mathematician, who was asked by a navigator what was the cause of a phenomenon, which undoubtedly would astonish those who had not read what we have just mentioned. It is asked, *why going constantly on the point east to reach a place really situated to the east of another, (by the shortest route,) one never gets there, but, on the contrary, always gets the farther from it?* The reason is, that by always following the same point of the compass out of the equator, and changing the meridian, we do not describe the arc of the great circle which measures the distance of two places, but a spiral or loxodromic curve, which will never pass by the spot required.

It is necessary to go on the loxodromic curve which passes by both places, or on a line which cuts the intermediate meridians under an angle equal to the angle of inclination of the loxodromic curve which passes by the two places [h].

Measure of the surface of the globe.

There are two points on the globe where there is neither *east* nor *west*; these are the two poles. The globe may also be considered with respect to the extent of its surface. We have seen, that it is 16,501,200 square marine leagues, supposing the earth a sphere. If we wish to know the extent of any zone whatever contained between two parallel circles, geometry teaches us, that the surface of a spherical zone is to the area of the sphere as the distance of the parallels which bound it is to the diameter; and this distance answers on the diameter to the difference of the sines of the latitudes of each parallel, as is seen on Fig. 6. by the line CK, difference between CP and KP. If, for example, we wish to estimate the zone comprised between

[h] Maupertuis, Discours sur la Parallaxe de la Lune, 2, 12, 13; 14. Mem. de l'Acad. des Scien. 1754. Varenius, ch. 39, &c. Dubourguet, Traité de Navigation.

the 48th and 49th parallels, and in which are Paris and its environs, we say,

The sine of 49° being	0,755
That of 48	0,743
The difference . .	0,012

Reduced to half 0,006, shows us that this zone contains the $\frac{6}{1000}$, or $\frac{3}{500}$ of the total area of the globe; which being estimated at 16,501,200 square leagues, we conclude that the zone contains 99,007 square leagues.

With this datum, we shall easily calculate the extent of each space comprised between two parallels and two given meridians; it is necessarily in the same relation to the entire zone, as the difference of longitude of the two meridians is to the entire circumference: we find consequently the value of the quadrilateral bounded by two meridians a degree distant, and by the 48th and 49th parallels, by taking the 360th part of the number 99007, which indicates the total area of the zone. This quadrilateral is about 275 square leagues.

Utility of the preceding calculations.

As all maps are divided by the meridians and parallels into quadrilaterals, which have commonly 1, 5, or 10 degrees, it is plain that a similar calculation for each zone and each quadrilateral, comprising a degree of longitude and a degree of latitude, would give a series of results, by the help of which one might estimate almost directly, either on the globe or on maps, the extent of each terrestrial region.

We should only have to examine how many quadrilaterals, of an equal value in degrees, were inscribed or circumscribed in the figure of the country we wish to measure, take the value in square leagues from the table, and then estimate that of the strips which might happen to fall out of the limits of these quadrilaterals. By these means, borrowed from *spherical* trigonometry, we should avoid the errors which almost necessarily happen when we wish to make use of the *scale* of a common map for measuring, according to the rules of *plane* trigonometry, the square surface of the different regions of the earth. Maps which re-

present a spherical surface on a plane surface, inevitably give the spaces too large or too small either in the centre or the circumference. Their *scales* or modules of measure cannot be applied uniformly to their surface.

A German geometer[1] has calculated from these principles, *tables of the square surface of the zones*, of which we shall insert a translation at the end of this work. We shall now show, by an example, the use of these calculations.

The state of Pennsylvania is limited to the north by the parallel of 42°, and to the south by the parallel of 39° 43′ 25″; it extends, in the direction of the longitudes, from 2° east (of Washington,) to 356° 37′ 30″ west. There is to the north only a small triangle towards the lake Erie, and a strip comprised in the bend of the Delaware, which extend beyond this figure; but as the surfaces to be added are very nearly balanced by the corners of the neighbouring states which enter into the quadrilateral, it may be considered as equal to the total surface of Pennsylvania. Now the four zones from 40° to 40° 30′, from thence to 41° to 41° 30′, and to 42°, should, according to the tables, have a surface of 217,345,077 square leagues, 20 to a degree. But the zone between 39° 43′ 25″, and 40°, is only 16′ 35″ in breadth. We must multiply, therefore, the surface of the entire zone of half a degree, which, according to the tables, is = 55312 square leagues, by $\frac{16' 35'}{30} = \frac{995''}{1800''}$. Which gives for the surface of this small zone 30599.11 square leagues; a sum which, added to that of the four zones of half degrees, forms a total of 24794.88 square leagues for the surface of the whole terrestrial zone comprised between the latitudes 39° 43′ 25″ and 40°. Now, Pennsylvania only occupying on this zone 5° 21′ 30″ of longitude, the area of the entire zone is to that of Pennsylvania as 360° to 5° 21′ 30″, or as 1,296,000 to 19,290;

[1] Klügel, Annuaire Astronom. de Berlin, pour l'An 1774, p. 173. Comp. Mayer, Introd. Complète à l'Art de Tracer des Cartes Géographiques, &c. p. 192. (en All.)

which gives for the surface of Pennsylvania 3690.48 square leagues, of 20 to a degree. It is evident, that this calculation might be abridged, if we knew, by the tables, what is the surface of a quadrilateral comprised between two meridians and two parallels, distant each by one degree, or half a degree: these quadrilaterals being counted, a simple multiplication would give the result required, allowance being made for the value of the incomplete quadrilaterals, which is easily estimated.

Remark on these calculations.

Geometers will perceive, that these valuations are rigorously exact, only on the supposition of the earth being spherical. The inequality of the degrees, which results from the ellipticity of the earth, occasions a slight difference between the area of a zone taken on a spheroid, and another taken on a sphere. But this difference, which depends on the quantity of the total depression of the globe, is very insensible, and amounts on a zone of 100,000 square leagues, under a mean latitude, only to 2 or 500 square leagues at most. Moreover, the geometers who have proposed algebraic formulæ to calculate the surface of the zones of the ellipsoid, and who have promised to publish tables calculated according to those formulæ[k], are of opinion that the irregularities of the terrestrial spheroid are not yet sufficiently known to be determined exactly.

Divers questions resolved by the globe.

We have considered the globe under its principal geometrical relations, and it remains for us, according to the ancient custom of geographers, to shew how various elementary questions are resolved by means of the artificial globe. But our readers are aware, that exact solutions of these problems can only be found by calculation; and besides, the questions commonly solved by the globe, are mostly either too vague or too foreign to geography to deserve any mention in this work. We shall confine ourselves to some short indications.

To find geographical positions.

To find on the artificial globe the latitude of any terres-

[k] De Zach. Correspond. i, 181—184. Pasquich, ibid. 413; ix. 301—308. Comp. Klügel, Annuaire Astron. Berlin, 1790, p. 243, *sqq.*

trial place, the globe must be made to turn round its immoveable axis till the fixed meridian be brought on that place; and the degree marked on the meridian at that point will give the latitude of the place. The longitude of the same place will then be found on the equator, at the point where this circle passes under the meridian. If we wish, on the contrary, to determine the position of a place, the longitude and latitude of which are known, we have only to make the point of the equator, which is at the given longitude, pass under the meridian, and, taking on the meridian the same latitude, we shall have the geographical position of the place.

The dial, which is commonly adapted to the north pole of the globe, serves to shew the hour in one part of the earth when it is noon in another; for, by placing the latter under the meridian, after having fixed at noon the needle of the dial, and making the globe turn till the meridian is on the place, the hour of which is required, the needle will indicate on the dial the hour wanted: it is *afternoon* if the globe has been turned to the east, and *forenoon* if it has been turned to the west.

To find the length of the days.

If we wish to know the length of the longest day for all the points of a hemisphere, the northern, for example, we must place the meridian, so that the border of the arctic polar circle touches the horizon of the globe: this horizon will then be confounded with the circle of illumination. If we bring into the meridian any point whatever of the proposed hemisphere, and then fix the needle of the polar dial at twelve, and make the globe turn towards the east till the point marked enters into the horizon, the needle will stop at the hour at which this point passes from the enlightened to the obscure part. The number of hours gone over on the dial will be the half of the duration of the day required. By placing the pole nearer the horizon, we shall give this circle the position which the circle of illumination takes in the times which precede and follow the solstices, and we shall find, as above, the length of the day in each country. In this position of the globe, all the points which are

at the same time on the western border of the horizon, are those which see the sun rise at the same moment that those on the eastern border see it set.

To find the points of the rising and setting of the sun.

The directions of the winds with respect to the meridian line, and the names assigned to them, are generally marked on the horizon. By this means we may ascertain the position of a place with respect to the sun, at the moment when it appears to rise or set, by observing on what point of the horizon the given place passes from the obscure to the enlightened part, or from this into the other. The globe, thus turned, affords the means of representing physically all the phenomena of the annual motion of the earth. It is sufficient to put in a dark room a globe with a taper, which answers perpendicularly to the centre of the horizon, and at a pretty considerable distance relatively to the diameter of the globe; we shall then obtain the same phenomena as the sun produces during the rotation of the earth, according to the different positions which the axis of the earth takes with respect to that luminary [1].

To measure distances.

The distance of two places is measured by placing one of those points on the meridian, then bringing above it the fixture of the circle of heights, and making this arc of a circle turn round its fixture, till it passes by the other point proposed. The number of degrees and parts of degrees marked at this point being reduced into itinerary measures, will give the distance required.

To rectify the globe.

If we wish to know on what line one of these places is situated with respect to the meridian of the other, we must first place the globe so that the second point may answer to the centre of the horizon, that is to say, we must *rectify* the globe for that point. This is done by taking its latitude, and making the meridian move in its *encastrement* with the horizon, till the elevation of the nearest pole is equal to this latitude. The horizon is then, with respect to the globe, in the position which the rational horizon of the place pro-

[1] Keil, Institut. Astron p 89.

posed, occupies on the earth. The globe being thus rectified, the fixture of the circle of heights is brought back on the place in question, and is afterwards made to pass by the first point. The number of degrees and parts of degrees comprised on the horizon, are then counted from the circle of heights to the meridian, either on the north or south side, and we have the measure of the angle formed with the meridian by the arc of the great circle which joins, by the shortest way, the two points proposed.

Another method to find the length of the day.

The problem of finding the duration of the longest day for any place, may also be resolved by substituting the rational horizon of the place for the circle of illumination. For this purpose the globe must be rectified for the place in question, and be placed in the meridian, the needle of the polar dial must be placed at XII. and then the degree on which the declination of the sun at the proposed moment falls, being marked, the globe must be turned till the point which corresponded to that degree of the meridian is in the horizon. The number of hours which the needle has passed over the dial, will be the number of those which elapse between the passage of the sun to the meridian, and its rising or setting. It is plain that the point taken under the meridian, at the same distance from the equator as the sun, goes over on the globe the same route as that luminary. The same process would make known the time that would elapse, in any place whatever, between the passage to the meridian, and the rising or setting of a heavenly body, whose declination is given; only the point that answers to this declination must be marked on the meridian. To determine the duration of twilight, we must trace, by means of the circle of heights, 18° below the horizon, a circle parallel to it, and determine the instant when the point taken on the globe to represent the sun, reaches that circle.

New construction of globes.

All these problems would be more easily explained if our globes were constructed after the new method proposed in part by G. Adams[m], but executed and perfected by

[m] *G. Adams*, Treatise describing the construction and use of new Celestial and Terrestrial Globes, Lond. 1766.

Covens[n]. Our readers will be able to judge of it from Fig. 18, of which we will give a short explanation. The great circular support ABC, which in common globes represents the horizon, here represents the ecliptic. On this broad band are two divisions, consecrated, one to the motions of the sun, the other to those of the moon. In the first we observe a subdivision indicating the 365 days of the common year, and another for leap year. A small artificial sun moves at will on the ecliptic. The exterior division of the ecliptic shows the longitude and latitude of the moon for each day of her *age*. The great brass circle PNM, perpendicular to the ecliptic, is a meridian circle, and especially the *colure of the solstices*. The axis of the terrestrial globe is fixed in this circle at the points FK, and inclined on the ecliptic under an angle of 66° 32′. In the poles of the ecliptic at the points L and G, rise two pins which bear a circle of celestial latitude. To this moveable circle are attached two stars, also moveable, and which can be placed under any celestial latitude or longitude we please. The semicircle FOPI, is the half of a circle of declination. CBD is the celestial equator, which forms with the ecliptic an angle of 23°, 28′. These are the celestial circles which do not turn with the globe, and which represent, as it were, an abridgment of the armillary sphere. On the globe itself, is a moveable semi-meridian RTQ. It is divided into degrees, counted on one side from the pole to the equator, and on the other in the inverse order. A great circle, VSW, is so fixed as constantly to preserve a perpendicular position on the meridian RTQ, at the same time that it may be made to coincide therewith; it serves to represent the rational horizon of any place whatever. Almost on the globe itself, in the plane of the equator, is a horary circle XYZ, attached to the meridian. The moveable sun performs the functions of the needle in the common globes.

It is easy to conceive the advantages of this new con-

[n] Covens, Hanleidung, &c. (Introd. à la Connaissance des nouveaux globes, &c.) Amsterd. 1802. Comp. Van Beek-Calkoen, in Zach. Correspond. xiv. 270.

struction. In the first place, it gives a much clearer idea of the horizon, as being a circle independent of the motion of the earth. To *rectify* the globe, or to place it at the height of the pole of a place, it is sufficient to bring the proposed place under the meridian RTQ, and then to push the horizon VSW to a distance of 90 degrees. On this globe the celestial circles are better distinguished from the terrestrial; the annual motion of the sun is better represented; in short, students will derive, from the study of such a globe, more precise ideas of the relations of our planet with the heavenly bodies which surround it.

Historical remarks on Globes.

We might here indulge in a historical digression on the successive improvements in the construction of globes, from that of Rogerk, immortalized by the commentary of Edrisi, down to the time of Blaeuw and Coronelli, who first made globes of elegant forms and considerable dimensions. We might investigate the origin of these instruments which were known to the ancients; inquire whether Atlas was the inventor of them, and whether the two famous capitals of the temple of Solomon [o] were a pair of globes;—whether Albert Durer, or Henry Glarean, first taught the art of drawing and engraving spherical segments, and of pasting them on a ball [p]: we might shew that the means of multiplying globes by engraving must have been generally known in 1530, since the cosmography of Gemma Phrysius was accompanied by a similar instrument, as our modern books are with an atlas [q]; —and finally, we might be allowed, perhaps, to describe the most famous terrestrial globes, such as that of Coronelli, framed at the expense of the Cardinal d'Estrées, and placed first at Marly, then in the king's library at Paris [r]; that of Gottorp, composed by Olearius between 1654 and 1664, and

[o] Fabricii, Bibl. Græca, lib. iv. c. 14. p. 464. Hauber, Hist. Des Cartes Geog. 57, and Supplem. 38, (en Allemand.)

[p] Zach, Corresp. xiii. (1806.) 156. Glareanus, De Geogr. c. 19. 1527. Vaugondy, Geogr. Institut. p. 359.

[q] Gemma Phrysius, De Prin. Astron. et Cosmogr. deque usi Globi, 1530. On the title: *Veneunt cum globis*; Lovanii, &c.

[r] De la Hire, Descript. les Globes de Marly, 1703.

which Peter the Great brought in a frigate, to adorn his new capital; that of Cambridge, which is 18 feet in diameter, being six feet more than any of the preceding; and many others, celebrated for their size or magnificence. But these historical researches would lead us too much from our subject. We shall only remark, that the copper globe placed in the library of the Institute, though incomplete with respect to modern discoveries, leaves all other great globes very far behind in the beauty of its execution. Bonaparte had one made, now in the Thuilleries, which does great honour to MM. Poirson and Mentelle.

Among the globes that come into the market, we distinguish those of Lapie and Poirson at Paris, made of a homogeneous mass of *papier maché*. Those of Sotzmann, published by Frantz at Nuremberg, are also esteemed, as well as those of Cary and Jones of London.

Besides armillary spheres and artificial globes, there are two other instruments of which the use may be recommended to young persons. One is the *planisphere* of Fortin, which represents the true planetary system in a new and more perfect manner; one can even perceive in it the ellipticity of the orbit of the earth. The other is the *geocyclic machine* of Loysel, calculated to demonstrate the motion of the earth. The use of it is explained in Mentelle's Elementary Cosmography. A taste for study should be excited in youth by this sort of scientific sports; but to expect a detailed description of them here, would be to appreciate but imperfectly the object of our work.

BOOK IV.

Continuation of the Theory of Geography. Of Geographical Maps. Of the Stereographic, Orthographic, and Central Projection.

LARGE globes are costly and inconvenient instruments; small ones do not exhibit sufficient details. It became necesssary, therefore, to have recourse to pictures, which, on a plane surface, might give a representation of the globe and its parts. These representations embrace either the whole earth, or a part of the world, or a single country. In the first case they are called *maps of the world*, and when they have a circular form, *planispheres;* those of the second class are called *general maps;* the others are *special maps.* Among the special maps, some represent a province on a large scale, with all its remarkable places; these are *chorographic maps.* If the designer has entered into all the details of the nature of the ground, or has even traced out insulated habitations, and the direction of roads and rivers, they are *topographical maps.* It is plain that these sort of maps must necessarily embrace a small district, and approach insensibly to *geometric plans.* Custom sometimes confounds these denominations. Geographical maps, properly so called, are also distinguished from those that are appropriated to a particular use; such are *hydrographic charts*, destined for mariners, *mineralogical maps*, and others[a].

Different sorts of geographical maps.

The figure of the earth prevents the possibility of giving a general picture, in which the distances of places, and the

[a] Mayer's Complete Introduction to the Art of Tracing Geographic, Hydrographic, and Celestial Maps, &c. Erlang, 1794, (in German.) Puissant, Traité de Topog. b. ii. p. 92—152. Comp. Rob. Vaugondy, Instit. Geograph. part ii. &c.

relative extent of regions, might be preserved in their mutual relations. There are curved surfaces, which can be extended on a plane without rent or duplication, and which for this reason are called *developable surfaces*; such are those of cones and cylinders: but others, like those of the sphere and spheroids, cannot be so extended. The earth being a spheroid, its surface cannot coincide rigorously with a plane; and thence results the impossibility of marking on a map, at the same time, and in their natural relations, the extent of countries, the distances of places, and the similitude of configurations. Geographers are obliged to have recourse to various constructions, to represent, at least in an approximative manner, each of these relations in particular. Developable surfaces.

These constructions have received the name of *projections*; a name applied in general to designs, the object of which is to indicate on a plane the dimensions of the sphere, and of the bodies it contains. They are of two kinds: some are real *perspectives* of the globe, or of the parts of its surface, taken from *different points of view*, and on different planes; the others are only a kind of developments, restrained to approximative laws, and appropriated to the relations which it is wished to preserve in preference. It is of the projections in perspective that we shall now occupy ourselves in this Book. Let us first explain the general theory of projection, as well as it can be done without the help of the higher geometry [b]. Of projections.

Projection, in the language of perspective, signifies the representation of an object on the perspective plane, or the plane of the picture. For, in every picture, there is supposed between the object to be represented and the point of view, a plane which intercepts all the rays of light directed from each of the visible objects to the point of view. Then we conceive a multitude of points of intersection of those rays

[b] See Euler, Acta Acad. Petropol. i. p. 1. Lagrange, Mem. de l'Acad. de Berlin, 1779. Molleverde, Analyse de la Projection Stéréographique, dans Zach. Correspond. xiv. 437, 528, *et seq.*

with the plane of the picture. The assemblage of these points is the image of all that lies under the view of the spectator. Each point of intersection is the perspective of the point whence emanates the ray of light, which having traversed the perspective plane, terminates in the point of view. In order that the perspective of a plane figure, as of a square, of a circle, &c. be a similar figure, two things are requisite; *first*, that the point of view should be in the axis of the figure; *secondly*, that the plane of the picture be perpendicular to that axis. If the plane to be represented is in another more perpendicular to that of the picture, it can only be represented by a straight line. A solid cannot be seen entirely in a single point of view, two at least are necessary. In order that a sphere be divided into two equal surfaces by simple perspective, the point of view must be at an infinite distance. The straight line, drawn from the centre of the globe to the point of view, is the axis of the great circle which separates the visible hemisphere from that which is not. It is called the *optical* axis.

The projection of the sphere is commonly divided into *orthographic* and *stereographic*.

Laws of orthographic projection.

Orthographic projection is that where the surface of the sphere is represented by a plane which cuts it through the middle, the eye being placed vertically at an infinite distance from the two hemispheres. Here are the principal laws of this projection[c]: 1*st*, The rays by which the eye sees at an infinite distance are parallel. 2*d*, A right line perpendicular to the plane of projection, is projected through a single point, which is that where this line cuts the plane of projection. 3*d*, A right line which is not perpendicular to the plane of projection, but parallel or oblique to it, is projected by a straight line terminated by perpendiculars brought on the plane of its extremities. 4*th*, The projection of the line is the greatest possible when it is parallel to the plane of projection. 5*th*, Thence it follows evidently, that a line parallel to the plane of projection is projected

[c] D'Alembert, Encycl. Method. art. *Projection*.

by a line that is equal to it; but that, if it is oblique to the plane of projection, it is projected by a line less than it. *6th*, A plane surface, if it is perpendicular to the plane of projection, is projected by a simple straight line; and this straight line is the line itself, where it cuts the plane of projection. *7th*, Thence it is evident, that the circle, the plane of which is perpendicular on the plane of projection, and which has its centre on that plane, ought to be projected by the diameter which is its common section with the plane of projection. *8th*, It is also evident, that an arc of a circle, the extremity of which would answer perpendicularly to the centre of the plane of projection, ought to be projected by a straight line equal to the sine of that arc, and that its complement is projected by a line which is simply the versed sine of that arc. *9th*, A circle, parallel to the plane of projection, is projected by a circle that is equal to it; and a circle oblique to the plane of projection is projected in an ellipsis.

Laws of stereographic projection.

Stereographic projection is that where the surface of the sphere is represented on the plane of one of its great circles, the eye being supposed at the pole of that circle. In the stereographic projection the globe is considered as a transparent solid. The hemisphere represented is that which is opposed to the hemisphere in which the eye is supposed to be. Here are the principal laws of stereographic projection.

1st, Every great circle, passing by the centre of the eye, is projected in a straight line. *2d*, A circle placed perpendicularly opposite the eye, is projected by a similar circle. *3d*, A circle placed obliquely with respect to the eye, is projected by another circle, the radius of which increases in the ratio of the obliquity. *4th*, If a great circle is projected on the plane of another great circle, its centre will be on the line of the measures, that is to say, on the projection of the great circle, which passes through the eye, and which is perpendicular to the circle to be projected, and to the plane of projection. The centre of the projected circle will be distant from the centre of the primitive circle, or of pro-

jection, by the quantity of the tangent of its elevation above the primitive plane, or the plane of projection. *5th*, A small circle will be projected through another circle, the diameter of which (if the circle to be projected surrounds the pole of the primitive circle) will be equal to the sum of the semi-tangents of the greatest and smallest distance from the pole of the primitive circle, these tangents being taken each in the line of the measures of the same side of the centre of the primitive circle. *6th*, In the stereographic projection, the angles which the circles make on the surface of the sphere are equal to the angles which the lines of their respective projections make among themselves on the plane of projection [d].

Setting out from these principles, methods have been found for tracing maps of the world according to either of these projections [e].

Three sorts of stereographic projections.

Three sorts of stereographic projections are in common use: 1*st*, That on the plane of the equator, called *polar*, because the eye is supposed to be at one of the poles. 2*d*, That on the plane of a meridian, commonly that of the Isle of Ferro, which cuts the globe into two *hemispheres*, one containing America and the other Europe, Asia, and Africa. 3*d*, That on the plane of the horizon of any place whatever.

Polar projection.

Let us first explain the method of tracing the polar projection. Supposing the eye at one of the poles, the picture will be itself the plane of the equator; the meridians will be projected by the straight lines, and the circles parallel to the equator by concentric circles.

Tracing of meridians.

The meridians are traced as follows: Let AP. fig. 19. be the radius representing that of the terrestrial sphere, and ABCD one of the great circles of that sphere. The centre P being taken for the projection of the optical axis, or of the point of view placed at the pole, the circumference ABCD will be the projection of the equator. But as the planes of the meridians all cut each other according to the axis of the earth, which is perpendicular to ABCD, the

[d] D'Alembert, loc. cit.

[e] Puissant, Topographie, 117, *sqq.*

projection of the first meridian may be represented by any diameter whatever; for example, by AB. Now, if we divide the semi-circumference ACB into 20 equal parts and if, through all the points of division, we carry diameters such as (1) (30), (2) (40), and so on, they will be the projections of the meridians corresponding with the longitudes A (1), A (2); the difference of longitude of the two meridians, traced in this way, will be 10 degrees, new French measure, or 9, ancient, since the arc AC, which is the quadrant, and equal to 100 new degrees, or 90 ancient, is divided into 10 equal parts.

Tracing of the parallels.

To obtain the projection of the parallels to the equator, spaced from 10 to 10 degrees, we must raise the diameter CD perpendicular to AB, and draw the straight lines D (1), D (2), D (3), and the following, which will cut the diameter AB at the points d' d'' d''', and so on. Then, by making the radii Pd' Pd'', turn round the point P, as the common centre, the circles will be described which are the required projections. In this method D is taken for a point of view, and the points d' d'' d''', are the stereographic projections of the corresponding points (1) (2) (3), belonging to the parallels of the 10th, 20th, 30th degrees; for if we conceive that the circle ABCD, turns round the diameter AB, till it makes a right angle with the plane of the figure, the radius PD will be perpendicular to this plane, the point C will be the pole opposed to the point of view D, and the circles A (1), A (2), &c. will be the respective latitudes of the parallels to the equator; consequently the traces A, d' d'', &c. of the visual rays DA, D (1), D (2), will represent on the perspective plane, the points A (1) and (2).

Equatorial projection, or on a meridian.

Let us pass to the stereographic projection on a meridian. In this method, the point of view, always placed in the centre of the hemisphere, opposed to that which is to be represented, is on the circumference of the equator, and the projection of this great circle is a straight line perpendicular to the axis of the poles of the earth.

Tracing of the meridians.

The meridians are projected in the manner we shall now indicate, by making use of Fig. 20. Let AB be the pro-

jection of the equator, PP′, the axis of the earth, and C the centre of the mass, or the projection of the point of view on the picture, on the plane of the meridian APBP′, the meridian we shall consider here as the first. All the meridians having PP′ for their common section, and their projections being circles, the circumferences of which necessarily pass through P and P′, it follows that their centres are on the right line AB. Let us divide as before the arc AP into ten equal parts, let us draw the diameter (1) (21), and through its extremities let us bring the right lines P′ (1), P′ (21), which will cut respectively AB, which we shall prolong, if necessary, to the points m' and n'; these points will be the projections, or the perspectives of the extremities of the diameter of the meridian of the map, passing by the point, the longitude of which, with respect to the first meridian AP′, is 10 degrees, new measure. If therefore, from the middle of m', n', as a centre, with a radius $=\frac{m'n'}{2}$, we describe the arc Pm' P′, we shall have the projection of the meridian required. By repeating the same construction for the points of division (2) (3), and the others, we shall obtain the projections o the other meridians; and, by a natural consequence of the symmetry of the figure, what we have constructed in the semicircle PAP′, will serve for the other semicircle PBP′. As to the meridian, the plane of which is perpendicular to the picture APB, it will be represented there by a right line which coincides with the axis PP′.

As the length of the radii, to describe the meridians, may become too great to trace these circles by means of a compass, a very simple instrument is used, composed of two moveable rulers, AC and CB, Fig 20. united at C by a hinge, which allows them to form any angle whatever. A pencil is placed in the centre of the motion of these two rulers, the point C is made to coincide with the point m', Fig. 21; at the points PP′ are fixed two small metal points, against which the edges of the rulers are applied, the point C always resting on m'; then, without varying the

angle ACB, the instrument is made to move, so that the rulers lean incessantly against the points PP'. The pencil C then describes the arc of the circle P*m'* P', Fig. 21. The demonstration of this process is afforded by elementary geometry.

Tracing of parallels.

Let us now indicate the projection of the parallels. These circular curves ought to pass by the corresponding points of division, (1) (19), (2) (18), (3) (17), &c. and their centres are necessarily situated on the prolongation of the axis PP'. We may determine, for example, the centre of the projection of the parallel (9) (11), in the following manner. Draw the straight lines B (9), B (11); the first will cut PP' at the point *r'*, the second at the point *r*, and the distance *rr'* will be the diameter of the parallel, which is moreover determined by the three points known (9) *r*, (11); we have only to describe an arc, the centre of which shall be in the middle of *rr'*, and the radius equal to the arc (9) P; it will be on the map the parallel of 90 degrees, new measure.

Horizontal projection.

We shall next consider the *horizontal stereographic projection*, the most interesting application of this method. The rational horizon of any place whatever, will serve as a plane of projection; the point of view is the lowered pole of that horizon; the meridian that passes through that place is represented by a right line, and is commonly called the *principal meridian*. Now let ABDE, Fig. 22, be the horizon of a place: its centre C will be the projection of the point of view, or of the pole of the horizon. Again, let AB be the diameter which represents the principal meridian. If the angle PCA is equal to the height of the pole, and DE be perpendicular to AB, the right line PE will cut AB in a point *p*, which will be the projection of the raised pole of the globe. If in like manner the line EP' is prolonged till it cuts the prolongation of AB in *p'*, this point will be the projection of the lowered pole of the globe. The projections of the meridians which will all pass through the points *pp'*, will have at the same time their centre on the right line SS', perpendicular on F, or on the middle *pp'*. SS' is called the *line of the centres of the*

meridians. It is remarkable that the line CF is equal to AT, which is the tangent of the height of the pole. To complete the determination of the projection of the meridians, it is sufficient to find a third point.—Here is a method to find that element [f].

Tracing of the meridians.

The meridian whose plane is perpendicular to the principal meridian AB, cuts the horizon according to the right line DE, perpendicular to AB; therefore, if from the point I as centre, and with a radius TD, we describe the arc DPE, this arc will be the projection of the meridian passing through the longitude of 100 degrees, new measure, or 90 ancient degrees, counting from the principal meridian AB. The projection of the equator does not present more difficulties; for if we raise the diameter QQ′, perpendicularly to PP′, this diameter will be that of the equator, and its projection on the map will be qq'. Consequently, if from the middle of the line qq', as centre, and with a radius $= \frac{qq'}{2}$, or equal to the cosecant of the latitude of the centre of the map, we describe the arc DqE, it will be the projection of the half of the equator. We must now recollect the principle on which the stereographic projections of two great circles of the sphere, make between them the same angles as the real planes of those circles. Hence is derived this geometric construction: From the point p as a centre, and with an arbitrary radius,—with an equal radius, for example, to pF, let us describe a circumference, and divide it into 40 equal parts, setting off from AB, (if we wish to trace, as before, only 40 meridians,) and through all the points of division radii must be brought, whose prolongations will meet the line SS′, or the line of the centres in different points a' a'', &c. These points will be the centres of the projections of the meridians. The practical employment of this process being often too embarrassing, on account of the increasing size of the radius R, we may determine, by the means we are going to indicate,

[f] Puissant, Topogr. p. 123.

the points where the meridians meet the planes of projection.

From any point whatever taken on the line AB, or its prolongation, from the point F, for example, is brought down perpendicularly Fk, on the line PP', making as we know already, an angle equal to the height of the pole, and the length Fk is carried from F to k': then from this last point as centre, and with a radius = Fk'', or with any other radius taken at pleasure, but rather large, a circumference is described, which is likewise divided into 40 equal parts. After this, secants k' n', k' n'', k' n''', are brought through all those points of division; the extremities n' n'', n''', of those secants, terminated in the right line SS', are on the very traces of the planes of the meridians; drawing therefore right lines, which pass through the centre of the map, such as n' C'μ', n'' C''μ'', n'' Cμ''', the diameters n' μ', &c. will be the required traces of the meridians; and as, moreover, they must all pass through the pole p, we shall have three points of each meridian, for example, μ''', p, m'''; the meridians therefore will be easily described according to one of the processes previously indicated. To trace the meridians by points.

In practice, as there commonly is not space enough round the map to perform this construction, founded on the principles of descriptive geometry, Fk may be carried from F to k''; this point will then be what is called the *centre divisor*; in other respects, the processes are the same.

Let us now examine how parallels to the equator are described. Their planes being perpendicular to the principal meridian AB, we shall obtain the diameters of their projections, as we obtained those of the equator, that is to say, after having divided the circumference ABDE into 40 equal parts, setting out from the point P, we draw, two and two, the right lines (1) E, (1') E; and the interval vv' intercepted between these right lines, and taken on the meridian AB, will be the diameter of a parallel. In the present, the parallel vv' belongs evidently to the 80th degree of latitude, since the arc AP measures the height Tracing of parallels.

of the pole. But for the parallels which are very distant from the superior pole p, the construction we have just indicated can no longer be put in practice, because the point v would then be too far from the centre of the map. To obviate this inconvenience, we may trace the intersections of the planes of the parallels, with the plane of projection ADBE, intersections which are necessarily parallel to the diameter DE, and distant from it by a sum equal. $\frac{\text{sin. lat. of the parallel}}{\text{cos. height of the pole}}$. When the latitude is southern, the pole p being the northern pole, this value becomes negative; and instead of bringing it on the side of AC, it is brought on the side of CB. Thence it follows that if at any distance whatever from the right line DE, (fig. 23.) the parallel line $d\,e$ is brought to it, the points d and e common to that parallel and to the circumference ADBE, will belong to the required parallel: but this parallel passes at the same time through a point such as v determined by the preceding method; we have therefore the three points necessary for tracing a circumference.

Properties of the stereographic projection.

There are other methods of explaining the three stereographic projections[6], but we prefer indicating in a few words the advantages and defects of this sort of projection. It is sufficient to cast one's eyes on a map of this kind, to perceive that the quadrilaterals comprehended between two meridians and two consecutive parallels, increase in extent in going from the centre to the circumference. This increase results from the obliquity which the visual rays take, on parting from an axis perpendicular to the picture, called the *optical axis*. It follows thence that the regions placed towards the borders of the hemisphere have a much more considerable extent than if they were at the centre, and that we are led into error whenever we compare them with those which occupy that part. For example, the point of austral Africa, appears much broader than on a globe, and in Nova Zembla the distances, south and

[6] R. Vaugondy, Instit. Geogr. l. c.

north are rendered by spaces much larger than the same distances are in India. This inconvenience, of no consequence to learned geographers, may lead pupils to false ideas; but this risk would be diminished, if, in teaching, care were taken to explain the qualities of stereographic projections, and to place under the view of beginners the polar, equatorial, and horizontal planispheres, the defects of one always disappearing in the other.

Measure of distances on a stereographic map.

The stereographic projection does not admit, in general, the employment of a rectilineal scale for comparing the respective distances of places, which are measured according to the arc of a great circle, joining these places: but we may always, by means of the graduation itself, measure the distance between the centre of the map, and any point whatever, and consequently we may know, on the horizontal projection relative to Paris, for example, the distance of that town from all the other points of the globe. This property results from this, that all the great circles which pass through the centre of the map, cutting each other according to the optical axis, have for perspective, right lines drawn through that centre, and admit of a graduation similar to that which is observed on the equator of maps of the world, constructed on the plane of the meridian.

If we wish to measure the distance from two points on a stereographic map, we may (Fig. 24.) make use of the following construction [h]. Let Z be the zenith of a place, C the centre of the horizon, or the projection of Z and ZMB, XMB′ the respective verticals of the two points MM′ given on the globe by their longitudes and latitudes. These points will have evidently for perspectives or traces *mm′*, supposing the eye in E. But if we prolong the right lines MM′, *mm′*, they will meet in a point R, and the right line COR will mark on the plane of projection CBB′, the trace of the plane MCM′ of the great circle to be pro-

[h] Puissant, Traité de Topogr. p. 127.

jected. Therefore the four points m, m', O, O', are on the projection of the great circle which passes through MM'; thus this projection, which is itself a circle, will be entirely determined. This being laid down, we may trace the shortest distance on the map, in the following manner. Carry Cm (Fig. 25.) from C to μ, and Cm' from C to μ; draw the right lines Eμn, E$\mu' n'$: then on mm' construct the triangle m' E' m, so that m E' be equal to μ E, and m' E' to μ' E; next, on the prolongations of E' m' and Em, draw μn from m to n'', and $\mu' n'$ from m' to n'''; finally, let the common section R of the two right lines $m' m$ and $n''' n''$, be determined, and draw the right line RCO, which will be the trace required. We may now trace the arc of a circle O' m' vm O, of which the portion $m' v m$ is the shortest distance. The number of degrees contained in the shortest distance, will be ascertained by considering the right line $n''' n''$, which is equal to MM' (Fig. 24. and 25.) as the cord of the circumference ADB.

Origin of the stereographic projection.

The stereographic projection was not known to the ancients. The first map of the world of this kind is found in a work of the beginning of the 16th century, by the same *Werner* of Nuremberg, who gave the first indication of the method of lunar distances[j]. He was indebted for the idea to his master, *Stabius* the astronomer[k]. The use of this projection appears to have been general 150 years later. *Varenius* marks its three modifications. *Hesius*, a German geographer, who lived in the beginning of the 18th century, applied stereographic projections to special maps. This method, laborious, but favourable to the exactness of the details of position, is little followed in France, where the stereographic projection is reserved for maps of the world.

Orthographic projections.

We shall now proceed to the explanation of *orthographic projections*, which might also be called *planetary*, since their

[j] J Werner, de quatuor orbis terrarum figurationibus, ad calcem. Ptolomæi geograph. lib. i. vers. ab eodem.

[k] Comp. Weidler, Hist. Astron. cap. xiv. nos. 3 and 4.

principal object is to show the direct image of the half of the globe, the eye being supposed at an infinite distance, that is to say, great enough for all the visual rays to be reckoned parallel. As these rays are perpendicular to the plane of projection, while the lateral parts of the sphere present themselves more and more obliquely to this same plane, it is easy to perceive, even without demonstration, that this projection, offering the contrary defect of the stereographic, makes the space diminish from the centre to the circumference. This diminution, which is infinitely greater than that remarked in the preceding projection, gives to the extremities of a planisphere orthographically projected, an aspect too much disfigured to fulfil, in general, any of the objects proposed by geography. This is a sufficient reason for indicating here only very briefly what regards orthographic constructions.

Figure 26, indicates the polar projection. The lines AB and CD, are two meridians which cut each other at right angles in E, which is the projection of the pole, and the centre of the map. The circumference ABCD is the equator, on the plane of which the map is projected. The circumference is divided into equal parts, from 10 degrees to 10, or from 5 to 5; the diameters which pass through the points *a' a''*, *b' b''*, &c. and by the centre E will be the meridians. Let fall from the points *a' b'*, &c. perpendiculars on the diameter CD; they will determine the radii E 1, E 2, &c. with which you will describe the circles parallel to the equator. Polar projection.

In the projection on a meridian, the process is constructed in the following manner. Draw the lines AB and CD (Fig. 27.) cutting each other at right angles; one will be the meridian of the middle, the other the equator. Their intersection E is the centre of the plane of projection, circumscribed by the meridian ABCD. This circumference must be divided into equal parts, then unite the points of division, the diameters *a' a''*, *b' b''*, &c. will be the common sections of the meridians, with the plane of the equator. The angles *a'* ED, &c. will mark the inclination of these Equatorial.

meridians on the plane of projection. Now let down from the points a' b', &c. on the radius ED, the perpendiculars a' 1, b' 2, &c. which will be the sines of the angles of inclination of those meridians measured on the equator; the parts E 1, E 2, &c. will be the versed sines of those inclinations, and consequently the lesser axes of the ellipses, which are to represent the meridians. The line AB, the projection of the axis of the globe, is the greater axis of those ellipses. The parallels to the equator are very simply traced; it is only necessary to join by a right line the points of division of the circle ABCD, equidistant from the diameter CD, and which are on the same side. This diameter being the projection of the equator, the cords a' (1), b' (2), and others parallel to it, will be the projections of the parallel circles.

The inspection of the figure shows the inconveniences of this projection; namely, the extreme narrowing of the lateral parts, and the obliquity, always increasing, of the angle under which the parallels cut the meridians. Nevertheless it is at the same time evident, that such a planisphere presents a more striking image of a spherical body than a stereographic hemisphere does; thus beginners, who cannot always study on a globe, by using from time to time a map projected orthographically, might perhaps imbibe more profoundly the idea of the sphericity of the earth. This advantage is still more sensible in the horizontal orthographic projection of which we are going to treat.

Horizontal projection and tracing of the meridians.

The meridians, in this projection, are ellipses, the greater axes of which coincide with the traces themselves of the planes of these meridians. These traces are determined by the same methods as those we have indicated for the stereographic horizontal projection. It only remains therefore to show how the smaller axes are obtained. Let (Fig. 28.) the angle DCP be equal to the height of the pole; let moreover m'' μ'' be the trace of a meridian, and DE the projection of the principal meridian. To have the orthographic projection of the raised pole P, let fall on CD the perpendicular P p, and you will have the point P. Now, to have

the angle which the plane of the meridian $\mu''\ pm''$ makes with that of the picture, or with the horizontal plane, we let down from the point p the right line R perpendicular on $\mu''\ m''$; $p\,R'$ is made equal to $p\,R$, and the right line $R'\,P$ is drawn, which forms with DE the angle required. The trigonometric relations of this angle, and of its cosine, then give this geometric construction: Draw C n parallel to R' P, and from the point n the right line nt parallel to P p; describe from the point C with a radius equal to C t, an arc tn', terminated at the meeting of C n', drawn perpendicularly to the trace or to the greater axis $\mu''\ m''$; then the line C $n\ x$ will be the orthographic projection of the radius C n, or the smaller axis required. We have then only to describe the ellipsis, the two axes of which are given.

Projection of the parallels.

The projection of the parallels, abstracting from the calculations which serve as its foundation, may be effected in the following manner. Supposing it is wished to project the parallel, the distance of which from the raised pole is measured by the arc P b or P a. From the points a and b are let fall on the principal meridian DE, the perpendiculars aa' bb', and the line $a'\ b'$ will be the smaller axis of projection of the parallel to be described. To find the greater axis, the cord ab is divided into an even number of equal parts; on DE are sought the projections of all the points of division, as has been done for the points a and b; then, after having drawn through those same points ordinates[1] into the semicircle $a\,x\,b$, they will carry the lengths of the first, on the correspondent ordinates of the ellipsis to be traced; by this means the principal points of this ellipsis are obtained, and the ordinate of the middle yx will be the semi-great axis $y'\ x'$ required.

Central projection.

Besides the orthographic and stereographic projection, there is a third projection in perspective called *central*. It

[1] An ordinate is a right line drawn from a point of the curve to another fixed line, which makes with the latter a determined angle.

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is obtained by placing the point of view at the centre of the sphere, and taking for picture a plane tangent to its surface. It would be useless to demonstrate how, in this case, the processes must be modified which we have given above to construct the equatorial, polar, and horizontal projections; from the point C of the figures 19—21, previously cited, we must draw the visual rays which determine the section made by the plane of the picture in the cones perpendicularly to the circles to be represented; we must take the picture parallel to that which passes through the centre and tangent to the circle ADBE. We then see that, in the projection on the plane of the first meridian, the meridians will be right lines perpendicular to the equator, which itself will be a right line; the parallels to the equator will be hyperbolas. In the polar projection the meridians will be right lines drawn from the centre of the map; the parallels to the equator, circles having their centre at that point; and in the horizontal projections, the meridians will be right lines drawn through the projection of the superior pole. The parallel of the place to which the projection relates will be represented by a parabola; those that are nearer the pole by ellipses; and the others on each side of the equator, by hyperbolas. It is plain that this projection alters still more than the stereographic, the extent of regions, in proportion as they are removed from the centre of the map. It can never represent an entire hemisphere, because the visual rays, brought by the circumference which terminates this hemisphere, are indefinite, being parallel to the plane of the picture; it may however be employed with advantage to retrace parts of the globe, the extent of which may not be very considerable; for, in this projection, all the places situated on the same great circle, are placed on the map on a right line[m]; it is susceptible of a sort of scale, the construction of which is not difficult to find. It was undoubtedly for this reason that

Properties of this projection.

[m] Lagrange, Mem. sur les Cartes Géographiques, dans les Mem. de Berlin, 1779, p. 162.

M. Prony thought of using it in the maps of the survey of France. This projection, almost unknown in geography, is employed for sun-dials.

Such are the three principal projections of the globe which the rules of perspective admit. We see that none of the planispheres traced after these projections unites all the qualities of a perfect representation of the globe; they necessarily alter the figure of countries, either in the middle or towards the borders of each hemisphere; they do not represent spaces really equal under equal dimensions; and the same takes place for most of the distances. It is not possible neither, to obtain, either in the stereographic or orthographic projection, that places situated in a right line on the globe, that is to say, on a same great circle, should be equally represented in the map of the world on a right line. Finally, the inequality necessary in the projection of spaces does not allow us to find with ease the exact longitude and latitude of a place. Different means for modifying the stereographic projection have in vain been proposed, with a view to remedy these inconveniences. The learned astronomer De Lahire[a] proposed that the eye of the spectator should be supposed out of the globe, and distant from its convex surface by the amount of the sine of 45 degrees; that is to say, that the meridian BD, Fig. 29, being of 200 parts, it must be prolonged out of the circle ABCD by 70 parts, and then from the point F, should be drawn the right lines Fa, Fb, &c. whose intersection with the diameter AE would determine the small axis Cx, Cy, &c. of the ellipses which represent the meridians. The geometer Parent observed that, in this projection, the radius of the meridian, distant by 45 degrees from the principal meridian, cuts in reality the semi-diameter into two equal portions, but that it may still be asked at what distance the eye must be placed that all the inequalities between the divisions of the semi-diameter should be the least possible; he found that if BD is equal to 200 parts, the point of view must be taken at a distance of 59½;

Faults of all the projections.

Modifications proposed by Lahire and Parent.

[a] Hist. de l'Acad. des Sciences, 1701, p. 97.

but it must be placed at $110\frac{1}{2}$ if we wish the zones of the hemisphere to occupy respectively a space proportioned to that which they occupy on the globe.

Thus, these sorts of modified stereographic projections, besides losing the advantage of presenting the meridians and parallels cutting each other at right angles, cannot preserve at the same time the equality of spaces and of configurations.

It is a truth generally admitted, that all the conditions of a perfect representation of the terrestrial surface can only be united in the case of the earth's being a cone or cylinder, or in short, any body whatever of simple curvature [o]. If therefore we can find a body of this nature, which approaches nearly to the spheroid, we may substitute its surface for that of the latter, and obtain representations which will answer one or other condition of a faithful picture.—This we shall explain in the following Book.

[o] Lambert, Mem. sur les Mathém. Mixtes, iii. p. 105. (en All.) Euler, Mem. sur les Solides développables, dans les Novi Comment. Petropol. xvi. 2.

BOOK V.

Continuation of the Theory of Geography. Of Geographic and Hydrographic Maps by Conic and Cylindric development. Of Projections by Proportional Parts.

Among all bodies which can be exactly retraced on a plane, the cone and cylinder have the most affinity with the sphere; the cone especially offers the advantage, that a small conic zone hardly differs at all from a spheric zone. Hence it is conic developments that afford the best projections of special geographical maps, and even by the help of some modifications for considerable parts of the globe. We shall therefore begin by the explanation of this sort of maps.

In the purely conic projection, a spherical zone is considered as confounding itself with the surface of a truncated cone which is tangent to it. If this surface be developed, the parallels become right circles of the summit of the cone, taken for centre; the meridians are right lines which all pass through this same point, and direct themselves towards the base of the cone. In order to fix our ideas better in this respect, let us have recourse to Fig. 30. Let PC be the radius of the sphere, M a place situated at the latitude EM, and OM the co-tangent of that latitude. The development of the mean parallel has for radius the co-tangent of its latitude, and for amplitude the arc equal to the circumference of which MR is the radius. Simple conic projection.

From the point O, taken for centre, and with the radius OM, we describe an indefinite arc NN', and taking OG for the meridian of the middle of the map, we make the angle NOM equal to the half of the number of grades contained in the mean parallel. Let us suppose, for example, that this parallel comprehends 25 degrees on the globe, and that the difference in latitude of the extreme

parallels is 30 degrees, the mean parallel will have on the map a number of degrees expressed by $\frac{MR}{OM}$ 25 degrees. Such is the amplitude of this arc, since the numbers of degrees contained in two arcs of the same length are to each other as their radii. Thus the angle MON being equal to $\frac{MR\ 25°}{OM\ 2}$, it is evident that the projections of the meridians will make between them angles less than on the globe, since MO is always greater than MR. Consequently, the parallels of the map, both the superior and inferior to the mean parallel, will exceed those of the globe of which they are the projections; and the more the map is extended in the direction of the latitudes, the more the two extremities will present an inexact proportion. To mark in the projection these extreme parallels, two parts M *a* and M *b*, equal to the half of the difference of latitude of the extreme parallels, are taken on the axis of the map OG; for example, at 15 degrees in the proposed case. These parallels are then represented by the arcs DD′ and EE′; and to conclude, the meridian of the middle and the mean parallel are divided into equal parts, which give the graduation of the map.

Modifications of the conic projection.

The faults of this projection are the not preserving equality between the spaces, and only giving true distances in the direction of the meridians. To remedy this, two means have been tried; one consists in taking, instead of the cone tangent, a cone inscribed in totality or in part; the other is to alter the rectilinear projection of the meridians.

If, in place of the arc *a b*, Fig. 31. we take the cord which subtends it for the side of the cone to be developed, the radii of the projections of the extreme parallels would be AO and BO, and the respective position of the points placed on the map would be in reality on these parallels; but those which would be between the parallels would by no means preserve their true positions. This method is good therefore only for a zone of little breadth.

The astronomer De l'Isle de la Croyere, who was employed to construct a general map of the empire of Russia, which, traced stereographically, would present shocking deformities, made choice of the conical projection; but, to improve it, he made the cone enter into the sphere, so that it cut it according to two parallels placed each at an equal distance from the mean parallel, and from one of the two extreme parallels. The map, by this means, had, on the two parallels just mentioned, the same dimension as the corresponding part of the globe; and its total extent differed but little from that of the country it was to represent, because the excess, which was at the two extremities of the map, was at least compensated in part by the deficiency which the inscribed portion of the cone had with respect to the spherical zone. The map comprising from the 40th degree of latitude to the 70th, the mean parallel answered to 55°, the parallels common with the sphere were those of 47° 30′, and 62° 30′. This projection presents many advantages for general maps of considerable extent, and the principal object of which is to show the totality of a vast empire [a]. Projection of De l'Isle de la Croyere.

The celebrated Euler made profound researches on this method of projection; he substituted for the determination of the parallels which should be common with the sphere, that of the point of concourse of the right lines which represent the meridians, and of the angle which they make between them when they comprehend a degree of longitude. His calculations rest on the following conditions: *1st*, That the errors should be equal at the south and north extremities of the map. *2d*, That they should also be equal to the greatest of those that take place towards the mean parallel of the map. He hence concludes that the point of concourse of the meridians should be placed beyond the pole by a quantity equal to 5° of latitude, and that the angle of two consecutive meridians should be 48′ 44″. He then investigates by how much the arcs of the great Method proposed by Euler.

[a] Mayer, Introd. à la Construction des Cartes, § 31, 32.

circles which measure the distances on the globe, differ from the right lines substituted for them in maps; and he finds that an arc of 90° would have on the map a length of 90° 79′, exact by less than near a hundredth [b].

Projections of Murdoch.

Murdoch, an English geometer, proposed three different methods for rendering the conical projection more conformable to the conditions of a good map [c]. This philosopher having explained himself in a laconic manner, his projections have been less appreciated by their real merit than they have been extolled or blamed without proof. We are indebted for a critical explanation of them to the researches of two German geometers [d]. We should deviate from our general method of not entering into abstract mathematical discussion, if we gave a complete idea of all the rules of these projections. The first presents two parallels perfectly similar to those of the sphere, and a conical surface equal in its totality to the spherical surface, but it narrows the distances towards the middle, and enlarges them at the extremities; the spaces even are not equal in dividing the map by two or several zones [e]. This projection of-

[b] Euler, Acta Acad. Petropol. i. p. 1.

[c] Philos. Trans. vol. L. Part ii. p. 554, *et seq.*

[d] Mayer, Introd. p. 298, 311. Albers dans Zach. Correspond. Astron. xi. 98—114, 240—250.

[e] "In Fig. 32, let C be the centre of the earth, Q a point of the equator, P one of the poles, QMP a meridian, A and B the points of intersection of two parallels. Let us suppose that $QA = \alpha = 70°$ of lat. (ancient measure) and $QB = \beta = 10°$. $QM = \mu = \frac{1}{2} = (\alpha+\beta)$ will be $= 40°$. Now the zone of the sphere, limited by A and B, must be represented on a conical surface equal in extent to the spherical zone, and so that the breadth of the spherical zone be equal to the arc BA. In other terms, the quadrilateral NO, $o\,n$ is required, which, turning round the axis $o\,n$, will describe a conical surface equal to the spherical surface described by the revolution of the segment BA, $a\,b$, so that NO in the cone remains equal to the arc BA."

We see that the line NO cuts the arc AB in the two points ζ and $\varkappa$, which are determined by the angles ζCM, and μCM, the sum of which is equal each to δ. If we take the radius of the sphere $= 57{,}29577$ degrees $= \varrho$, we shall find $\cos\delta = \frac{\sin\frac{1}{2}(\alpha-\beta)}{\frac{1}{2}(\alpha-\beta)}$.

"We thence conclude $Kp = R$, the semi-diameter of the projection in de-

fers, nevertheless, a representation sensibly faithful, when the application is made only to zones of 8 or 10 degrees of latitude. The object of the second projection of Murdoch is to obtain the exactness of the perspective, by plac-

grees of latitude R = Kp = ϱ. co-tang. μ, cos. δ; or, if we suppose ϱ. 15 = r, in geographical miles R = r. cot. μ, cos. δ."

"In the example given, we shall have δ = 17° 16″, consequently $\varkappa = \mu + \delta$ = 40°+17° 16′ = 57° 16′, and $\zeta = \mu - \delta$ = 40° — 17° 16′ = 22° 44′, finally R = 978,1 geographical miles."

"As besides KO = MA = 30° = 30.15 = 450 geographical miles, and KN = MB = 30° = 30.15 = 450 g. m. we know the two extreme circles of the conical zone by their semi-diameters, namely: pO = R — KO = 978,1—450 = 528, 1 geogr. miles, and pN = R + KN = 978,1 + 450 = 1428,1 geog. miles."

"Fig. 33 represents a projection conformable to these data, and comprehending 110 degrees; but as yet we only know the semi-diameters for the latitudes of 10° = pN, of 40 = R, and of 70° = pO. It is evident that the two triangles pkK, and CFM are alike, since the angles k and F are both = 90°, and the angle p = MCF = 90°—MCp. From this is easily drawn the proportion CM : MF = pK : Kk and as CM = to the total sinus = 1 and MF = *sin.* μ, we shall substitute for pK any geographical longitude whatever, for which we choose to calculate the angle SpW = λ, and to Kk, the angle required SpW, we shall have the proportion 1: *sin.* $\mu = \lambda$: SpW that is to say: SpW = λ *sin.* μ.

"In our map, which should comprehend 110 degrees of longitude, the angle S p W will be = 110. sin. μ. Therefore,

Log. λ = log. 110 = 2,0413927
+ Log. sin. μ. = log. sin. 40° = 9,8080675 — 10
Log. S p W 1,8494602 = log. 70,7066

and, consequently, the angle S p W = 70° 42′, since there is no inconvenience in regulating the 0,0066 which make 24″.

"Now, the angle S p W on the arch SW is divided into 11 equal parts, and by that are determined the meridians of the map from 10° to 10°" (Albers, loc cit.)

This author afterwards shows how, taking a principal meridian s t, one may calculate the points of intersection of all the meridians with the extreme parallels.

He afterwards gives, for the determination of the remaining parallels, the following method, conformable to the conditions which Murdoch imposed on himself. "K $\varkappa$ is = Kζ. In the triangle CK $\varkappa$, which is rectangular in K, the side K $\varkappa$ = r sin. KC$\varkappa$ = r sin. δ; and in like manner in the triangle CK ζ, the side K ζ = r. sin. δ. For our map we shall have

Log. r = log. (57,29 . . . × 15) = log. 859,4366 = 2,9342139
+ Log. sin. δ = log. sin. 17° 16′ = 9,4724982 — 10
Log. K $\varkappa$ = log. K ζ = 2,4007061 = log. 255,1

ing the eye in the centre of the globe as in the central projection; but, for this condition to be fulfilled, it is necessary that the map should be folded in a conical form, like the celestial *coniglobia*, published in Germany by Funk. This latter projection is susceptible of an increasing scale, like the hydrographic maps of Mercator, of which we shall speak hereafter. The third projection of Murdoch seems to offer nothing advantageous.

Conic globes.

However ingenious the modifications may be by which it has been attempted to perfect the conical projection, it is evident that they all tend to make it lose its primitive simplicity and facility without obtaining completely the advantages proposed. In the projections after Murdoch and Euler, there is always some part of the map where the spaces are a little too large or a little too small; the errors on the distances, in Murdoch's first projection, may go to $\frac{2}{11}$. It is true that this projection, corrected by Albers, offers such proportions, that in the smallest square, circumscribed by two parallels and two meridians, the defects of more or less destroy each other, so that the spaces are everywhere in the just proportion; nevertheless the distances taken in the direct sense of the four cardinal points, are not found exactly, and the configuration of the countries is altered in those same directions.

Albers's projection.

Geographers have therefore sought, for their special maps, more commodious projections, and which only refer very indirectly to the development of any regular figure whatever.

"It is sufficient," says an illustrious geometer, "for the mathematical exactness of a map that the parallels and me-

Therefore $K\varkappa = K\zeta = 255{,}1$ geogr. miles, whence we easily conclude $p\varkappa = p K - K\varkappa$ and $p\zeta = p K + K\zeta$."

But Murdoch is satisfied with tracing the parallels by dividing TS or VW, Fig. 33, into equal parts; an irregular process, contrary to the conditions of the problem, and which nevertheless diminishes the faults of the map. M. Albers discovered a geometrical law for tracing parallels so as to render the spaces more conformable to those of the sphere. See the complete memoir of Albers in Vol. xii. of the Annals of Voyages and of Geography.

ridians be traced after any constant geometrical law whatever[f]." One may imagine therefore a great number of projections, among which it will suffice to notice a few.

The first method proposed by Ptolemy for drawing the world, as known in his time, is an alteration of the conical projection, nearly the same as the method of Delille[g]. He places the eye in the plane of any meridian whatever of the hemisphere containing the known world, and on the prolongation of the radius of the sphere which cuts that meridian at 45° lat. N. He afterwards makes "the globe turn so that the meridians present themselves successively to the eye as right lines uniting at the pole, and the parallels show themselves as arcs of a circle having their convex part towards the south." These words prove that there is no question whatever of a stereographic perspective; the position of the eye is only indicated to demonstrate the possibility of seeing the meridians projected by a right line. The relations of the arcs of the parallels in this projection (Fig. 34.) are determined after an arbitrary scale, the result of which is to render the arc of the meridian PF = 40,000 stadia, exactly proportioned to the arc of parallel of lat. of Rhodes HKL = 72,000 stadia. The parallel of lat. of Thule ŌPQ and the equator RST, have also between them the same proportion as on the globe; but they are too great compared to HKL. As Ptolemy extended the known world to 16½ degrees south of the equator, he traces at this latitude the *antiparallel* of Meroe, a place situated at 16⅔° to the north of the equator; he divides this arc like that which passes through Meroe, and marks the meridians by drawing right lines between these points of division and those of the equator. This projection is, as we see, only a rude alteration of the conical projection; and even Ptolemy prefers another method, of which we shall give a rapid sketch[h].

First method of Ptolemy.

[f] Lagrange, Mem. sur la Construction des Cartes, sect. 2.

[g] Ptol. Geogr. i. cap. 21.

[h] Ptol. Geogr. i. cap. 24.

Second method of Ptolemy.

The eye is placed in the plane of the meridian which divides the known world through the middle, and on the prolongation of the radius of the sphere, drawn by the common intersection of this meridian with the parallel of Syene, considered to be the mean parallel of the known world. Consequently, let ABCD, Fig. 35. be the great circle which circumscribes the hemisphere, containing the world known by Ptolemy; let A and C be the poles, BFD the equator, AFC the mean meridian of the known world, and E its point of intersection with the parallel of Syene; then a line drawn from the centre T, through the point E to S, will be the line in which the eye is. If now a great circle, of which BED is the half, is drawn through the point E, the eye will also be in its plane, because it is in its common intersection with the plane of the meridian AEC. Hence, Ptolemy concludes, that the semicircles BED, and AFC, will present themselves as right lines, which cut each other at right angles; that on the contrary, the equator and all its parallels, seeing that their planes have the same inclination to the plane of the great circle BED, in which is the eye, will appear as arcs of parallel circles, having their convex part to the south: finally, that the meridians situated on both sides of the mean meridian AEC, will be seen as arcs of a circle, the concavity of which is turned towards the mean meridian, and which become more and more concave as they remove from it." But instead of developing these principles conformably with perspective, Ptolemy determines the lines of his projection according to arbitrary proportions, combined so as to preserve as much as possible the configuration of the countries.

"Trace," says he, "the rectangular parallelogram ABCD, Fig. 36, so that the side AB be double the side BD. Cut it in two equally by the perpendicular EF, which you will divide into 90 parts. Prolong this line by 91 parts, $\frac{5}{6}$ to have the centre L. Take FG of 16 parts $\frac{5}{12}$, to trace from the opening LF the parallel of Meroe SX. Make GH of 23 $\frac{5}{12}$ to have with the radius LH,

the tropic of Cancer TY. Take GK of 63 parts, and from KL, describe the parallel of Thule QR. Bring on these three parts of circumferences TY, QR, SX, the degrees suitable to the parallels which answer to them, and in the relations which they have with those of the equator; and through the corresponding points QTS, RXY, &c. make portions of circumferences pass; they will be the meridians required.

Modification of Ptolemy's projection.

This projection is also employed, though with essential modifications, to depict considerable parts of the globe. The best of the methods, which are derived in some sort from that of Ptolemy, is that employed by Flamstead in his celestial atlas, the improvement of which, if I am not mistaken, is owing to Bonne, one of the best French geographers. The principles of this development are to describe all the parallels from the same centre, taken in the axis of the map, and to take afterwards on each parallel the degrees of longitude as they are given by the law of their decrease, that is to say, proportional to the cosine of their latitude, and last of all, to make a curve line, which represents the meridian pass through the same series of corresponding points of division. Whatever be the position of the centre on the axis of the map, this projection enjoys the property of representing by equal quadrilaterals, each corresponding quadrilateral formed on the surface of the globe by any two meridians and parallels whatever[1]. The quadrilaterals, moreover, have two of their opposed sides equal in length to the corresponding sides on the sphere, though different by their curvature. The first meridian is rectilinear, and cuts all the parallels at right angles; the rest are curves which cut them more or less obliquely as they remove from the principal meridian; from which the quadrilaterals they comprehend lengthen in the direction of one of their diagonals, and contract in the direction of the other. This is the principal defect of this development;

[1] Mollweide, Démonstr. Analyt. de la project. &c. Zach. Corresp. Astron. xii. 144.

but it only becomes sensible at a considerable distance from the centre of the map.

Flamstead's projection.

This defect was very sensible in Flamstead's atlas, because that astronomer, having prolonged indefinitely the axis of his map, traced the parallels by infinite radii, that is to say, that they are in the map, right lines cutting the meridians of the exterior of the map, under very oblique angles; whence results a great alteration in the configuration of the countries remote from the centre, as may be judged from Fig. 37.

Correction of this projection.

This inconvenience is obviated by drawing the mean parallel of the map so that it may be cut perpendicularly by all the meridians. For this, it is sufficient to take a right line, equal to the cotangent of the latitude of the parallel which divides nearly equally in the direction of the meridians, the region we propose to represent, and with this right line as a radius, to describe the mean parallel of the map; the other parallels will describe themselves from the same centre with the same radius, augmented or diminished by a quantity equal to the part of the meridian comprised between the mean parallel and that to be traced. It is unnecessary to say that we should also make the principal meridian of the map agree with that which, in the direction of the parallels, divides the map into two equal portions. It is a principle which must be observed in all the developments of the globe.

The corrected projection of Flamstead being now the most generally adopted, we think it right to make known the processes thereof, according to the method adopted in the *Depot de la Guerre* [k].

Tracing of Flamstead's projection corrected.

Let us propose to apply these principles to the development of a spherical semi-spindle, the angle of which is 100 degrees, new measure. The development will be the projection of a triangle with three right angles, or of the eighth part of the surface of the sphere. In Fig. 38, let C*a* be the representative radius of the proposed sphere, and *a* O a

[k] Puissant, Traité de Topog. p. 138.

line perpendicular and equal to C*a*. If from the point *a* we let down on Co the perpendicular *ae*, it will be the radius of the parallel at the lat. of 50 deg. (new measure), taking P for the pole, and Q for a point of the equator. This being done, we may consider *a*O as the side of a cone-tangent to the sphere; and then the surface near the circle of contact will coincide sensibly with the spherical surface. But, since, on one hand, we have to develope only the quarter of the circumference of which *ae* is the radius, or which comes to the same, the quarter of the curve surface of the right cone which has O*a* for side, and that, on the other hand, *ae* is the sine of 50 degrees, when the radius *a*C is taken for the total sine, we shall have the logarithm of the sine of 50° = 9,8494850, and the sine of 50°= 0,70,711. Then $\frac{1}{4}$ of the circumference which has for radius *ae*, is = 1,1101627; finally, since the arc *a* M *b*, (Fig. 39.) described with a radius *a*O = 1, should have for length 1,1101627, we shall find the number of degrees of this arc by the following proportion:

3,14 : 200° : : 1,1101627 : *x* = 70°, 71.

Such is the value of the angle *a* O *b*, or the amplitude of the arc *ab*, Fig. 39. Now, if we wish to have the degrees of longitude from 5 to 5, we must divide the arc *ab* into 20 equal parts, and the middle M of that arc will be on the axis OM of the map. But as it is not possible to determine the position of the other parallels, as well as the length of their respective degrees, without having a scale of equal parts, constructed according to the number of metres contained in the mean radius *a*C of the earth; a radius which, as we know, is = 6,366198 metres, we shall proceed previously to the construction of this scale. For this purpose, we must bring on an indefinite line *m*C', Fig. 40, 636 parts, and $\frac{6}{10}$ from C' to *m*, and must take *a'* C' equal to the radius *a*C, Fig. 38; then through all the points of division of the line *m*C, are brought parallel to *a' m*, the right lines *xx'*, *yy'*, &c. The line *a'* C' being by this means divided into parts proportional to *m*C', we form on this module the scale of the Fig. 39. Scale of the map.

Having thus constructed the scale of the map, we take in it a length of 50 parts, or myriametres, for the value of the degrees of the meridian, taken from 5 to 5, and we carry that length on the axis of the map, ten times above and ten times below the mean parallel *a b*, Fig. 39. We then describe from the point O, as centre, indefinite arcs, passing through all the points of division of the axis OM; we as then have the parallels from 5 to 5 degrees. Finally, on each parallel, we take distances equal each to five times the value of the degree of longitude, known by the geographical tables. Thus, on the parallel of 55 degrees, the length of the degree of longitude is 6 myriametres 49; consequently, we must, setting out from the axis of the map, and on both sides of that axis, carry ten times the interval $6{,}49 \times 5 = 32$ myriametres 45, taken on the scale. When all the points through which the meridians must pass have been determined in this manner, it is easy to trace those curves.

It must be confessed, that the amplitude of the arc of any parallel whatever, determined by this method, will be a little greater than it ought to be, since we give to the cord of an arc of 5 degrees, the length itself of that arc; but the error which results from it is the less, according as the curvature of the parallel is smaller. Moreover, to obtain a rigorous exactness, we may determine the amplitude of all the parallels like that of the mean parallel, by the angle of which the two radii brought to the extremities of that parallel form.

Remark on the scale of the map.

Instead of taking arbitrarily, as in the above example, the radius of the sphere, the length is most commonly fixed by means of a scale constructed beforehand, the parts of which also are in a determined relation with the metre. For example, in the *Depot de la Guerre*, the scale for the drawing and engraving of the map of each of the four parts of the world is $\frac{1}{2000000}$, that is to say, that 2,000,000 metres taken on the ground, will be represented on the map by the real length of a metre. According to this, the radius of

the earth, which is 6,366198 metres, will be only on the map $\frac{6\,m.\ 366198}{2} = 3^m.\ 18$. Hence, that the scale of this map may be divided from 10 to 10 myriametres, or from 100000 to 100000 metres, it is necessary that 10 myriametres have 5 centimeters of length. The *Depot de la Guerre* observes, in like manner, in its special maps, a decimal progression of the scale, so that the degree of latitude of a general map being taken for unity, that of the chorographic map should be represented by one of the numbers 2, 5, or 10, which are exact divisors in the decimal system. By this means, the particular maps are perfectly connected with the general maps, seeing that the proportions of details increase from one to the other map, in relations of easy calculation. But the execution of those maps, by requiring the largest size paper, increase their price too much.

The various modifications of the conical projection having been sufficiently explained, we shall now consider the *cylindrical developments* of the surface of the globe, and the marine charts deduced from them [1]. Cylindrical developments.

The *points of the compass* which navigators follow, having the property of cutting under the same angle all the meridians which they traverse, and which, for that reason, form on the globe the spiral named *loxodromic*, are necessarily projected by curve lines, of the same kind in all maps where the meridians are not parallel. This is demonstrated by Fig. 41, in which we see a half of a hemisphere projected on the plane of the equator. Let P be the north pole, AMB the equator; the right lines drawn from the centre to the circumference are meridians, and the concentric circles represent the parallels. Supposing the navigator wishes to go from C, a point of the equator right north-west, the course of his vessel must constantly make with the meridian of the place, or with the line north Of loxodromic lines.

[1] Neptune Français, Disc. prelim. Bezout, Cours de Mathém. Marine Dubourguet, Traité des Navig. &c.

and south, an angle of 45 deg. (an. meas.) Supposing him to be arrived at G, the meridian line GNP, preserves no longer its parallelism with the meridian CG; if he continues his route norh-west, keeping always the angle of 45°, he will reach the point H, to the point from J, and will thus describe the loxodromic curve CG H I, which constantly approaches the pole, without, however, ever reaching it. The greater the constant angle under which the route cuts the meridians, the longer the loxodromic curve becomes, as is seen in Fig. 41, by the line CRS. It is plain that mariners, who must direct their courses on these lines, cannot conveniently trace on these maps, neither the road they have made, nor that they have still to run, on account of the difficulty of measuring with the compass the arc of a curve. To obviate this inconvenience, they have endeavoured to contrive a projection of maps, in which the meridians should be right parallel lines.

The development of a cylinder immediately presents itself to the mind, as the means of obtaining such a projection. When we merely wish to trace a zone of very little extent in latitude, it is evident that the spherical zone may, without any sensible error, be represented by the development of a cylinder, either inscribed, or circumscribed on that zone, and the axis of which coincides with that of the globe. The meridians which will result from the sections of the cylinder, by planes passing through its axis, are represented by right lines parallel to that axis; the planes of the parallels cut the cylinder according to circles parallel to its base, and which become right lines in the development.

Construction of flat maps.

Such is the construction of flat maps, the invention of which is falsely attributed to Don Henry, Infanta of Portugal, since Marinus of Tyre, anterior to Ptolemy, condemns their use, and has attempted to modify them [m]. Their defects are analogous to those of the conic projection; they are even more considerable; for, in the latter, one may

[m] Marin. Tyr. Ap. Ptolem. l. 20. Comp. Gosselin, Recherches sur la Geogr. des Grecs, li. 33. *sqq.* i. 46—50, &c. &c.

give two parallels their true length with respect to the degrees of latitude, while on the flat map this proportion can be observed with respect to one only; namely, for the inferior, in the development of the circumscribed cylinder, and for the superior in the development of that which is inscribed. It is true that one may avoid this inconvenience, by employing a cylinder constructed on one of the intermediate parallels, which would be partly interior, and partly exterior to the sphere; in this manner, the extent in longitude would be exact towards the middle, but the error would be divided between the two extremities. Cylindrical projections have even been attempted, in which the basis of the cylinder would be any vertical circle whatever [n]; but we shall not mention them, and shall merely observe, that the parallel which serves as base to the cylinder, may be placed so as that the area of the development shall be equal to that of the spherical zone.

The tracing of flat maps is effected without difficulty, as soon as the position of the terrestrial parallel to be developed is fixed; it only remains to give to the degrees of longitude on this parallel, the size they ought to have with respect to that which is assigned to the degree of latitude.

Defects of flat maps.

The line HG, Fig. 42. being supposed parallel to the axis CP, and equal to the development of the arc BF, will be the meridian of the map destined to represent the zone comprehended between the parallels of the points B and F. The development of the mean parallel, the radius of which is E *e*, will give the degrees of longitude. This figure shows the defect of the map on the extreme parallels, since the radius G *g* is smaller than B *b*, and the radius H *h* larger than F *f*.

These maps can only serve for very small parts of the globe; the least defective are those which represent the regions near the equator, because at a little distance from this circle the cosines of the latitude do not vary much. D'Anville made use of them in such a case [o], but it was almost unique.

[n] Textor, dans Zach, Corresp. xviii. 190.

[o] Carte de Guinée, 1776. D'Anville, Consid. sur la Géogr. p. 30.

Mercator's projection, or reduced maps.

Nonnius remarked, towards the middle of the 16th century, the defects of flat maps. Mercator, who had just introduced the stereographic projection for maps of the world, considered that mariners do not employ maps to know the figure of countries, but only to trace exactly, according to its length and direction, the course they have made, and to determine the distance they are from different points of the coasts, with the course they must hold to reach or avoid them; he invented, according to this principle, in 1550, the projection of *reduced maps*, which perfectly satisfies these conditions, and of which Wright, Gregory, Halley, and others, discovered the mathematical theory long after [p]. The meridians are here parallel right lines, equidistant and cut at right angles by the parallels to the equator; but the intervals which separate the latter, increase as we advance towards the poles, in an inverse relation to that which the diminution of the degrees of longitude, (Fig. 43.) follows on the globe. Hence it results that the distances in longitude, measured on each parallel, have, with respect to the distances in correspondent latitudes, the same relation as on the globe.

The tracing of these maps has no difficulty but the construction of the scale of latitudes, for which tables have been long since calculated with much care, and even with an allowance for the flattening of the earth. They bear the name of tables of *increasing latitudes*, on account of the augmentation which the length of each degree of latitude has in these tables in proportion as it approaches the pole. As the principles according to which these tables are constructed cannot be rigorously explained without the aid of the integral calculus, we shall confine ourselves to an observation on the nature of reduced maps, and shall indicate hereafter a simple enough method to arrive at the construction of these tables by approximative means [q]. It is evident that we must not look in them either for the relative

Tables of increasing latitudes.

[p] Mollweide, dans Zach, Corresp. xiv. 190.

[q] See Note, p. 137.

extent of countries, or for the exact image of their configuration; for this projection augments considerably the regions placed towards the poles, though in other respects it shares with the stereographic *projection* the property of preserving their similitude to infinitely small portions of the globe; but these defects have no inconveniences in maps, which should only be considered as instruments destined to resolve geographically the principal questions in navigation, which they do with the greatest exactness and facility, by means of geometrical formulæ given in treatises of navigation.

Proportional projections.

It still remains for us to point out various methods of tracing maps, which have not the development of a figure for their basis, but only calculations of proportion.

Projection of Lambert.

The most remarkable projection of this kind is that invented by the celebrated geometer Lambert[r], and since examined by an Italian author[s]. The principal condition of this projection is to represent, by equal spaces, regions of equal extent. To construct the map of a hemisphere it is conceived to be divided into semi-spindles, by planes brought through its axis; and on the centre of the great circle perpendicular to this axis, another is described, the area of which may be equivalent to that of the hemisphere It is easy to see that each semi-spindle will be represented on the circle in question by a sector, the angle of which will be equal to that formed by the two planes which comprehend the spindle. This is shewn in Fig. 44. in which P represents the pole, ABD the plane of the equator, APB a semi-spindle comprised between two meridians and the equator; the circle A′ B′ D′ is that the area of which is equal to that of the hemisphere PABDE. We discover also without difficulty that the radius A′ C must in general be equal to the cord AP of the arc of the meridian comprised between the pole and the plane which terminates the spherical dome to be represented.

[r] Lambert, Mem. sur l'usage des Mathem. vol iii. Observ. sur les Cartes, sect. 99. Mayer, Introd. &c. sect. 52. en All.

[s] De Lorgna, Principi di Geogr. &c. Verona, 1789.

Polar projection.

In the polar projection, traced according to this principle, the meridians are the radii of the circle which terminate the map; the parallels are concentric circles to the former, described from a radius equal to the cord of the complement of the latitude; the quadrilaterals formed by the meridians, and the parallels which terminate a zone, are equal and rectangular as on the sphere; and for this reason the configuration of the countries is not very much altered. The distances are not measured immediately by the right line which joins the two points compared, but it does not differ much from them, and its exact value may be pretty easily described. This projection is also very easy to describe when it is employed to represent hemispheres terminated by the equator; but it becomes more complicated when the hemispheres are terminated by the horizon, because we must there substitute for the meridians and parallels the *azimuth* circles and the *almicantarats* (or parallels to the horizon) of the place taken for centre of the map, circles to which the longitudes and latitudes can be referred only by a construction or particular calculation.

Equatorial projection.

The inconveniences seem less in the projection of the hemispheres terminated by the meridian. A German geometer[t] has given an analysis of them, from which the following graphic process has been deduced. Trace a circle with the radius AC, Fig. 45; cut it by the lines AD and BE, one representing the equator, the other the meridian of the middle of the map. Mark the cords representing the parallels by dividing the semi-diameters BC and EC, each according to the following scale, the radius AC being taken for unity.

Latitude 10° — 0,13681	Latitude 60° — 0,76239
20 — 0,27201	70 — 0,86191
30 — 0,40397	80 — 0,94539
40 — 0,53094	90 — 1,00000
50 — 0,65116	

Finally, divide both the equator and parallels into equal

[t] Mollweide, dans *Zach*, Corresp. xii. 160. Voyez les Annales des Voyages, vol. xiii.

parts, and carry through the corresponding points of division, ellipses representing the meridians. This projection has some resemblance with the orthographic, but is more easy to trace; it disfigures the countries infinitely less, and gives the spaces in their just proportions.

Alteration of this projection.

We may consider as an arbitrary alteration of this proportional projection, the method of which the idea is attributed by Vaugondy to G. De L'Isle [u], but which is indicated in more ancient authors [x]. It consists in dividing the principal meridian, the equator, and the circumference of the map into equal parts, and then carrying through the points of division, curves representing the meridian and parallels. Arrowsmith's maps of the world are traced according to this method, which has nothing particularly recommendable.

Projection of Cassini.

The operations of Cassini, to determine the figure of the earth by the measure of the degrees of the meridian, and the parallels, gave rise to a very important kind of projection, being that according to which the great map of France, the finest geographical work ever executed, is constructed [y].

When it was attempted to measure a degree of longitude, the difficulty was experienced of tracing exactly on the earth a parallel to the equator. In fact, if, by a line directed by means of vertical pegs, and perpendicular to the meridian of a place, we determine a series of points, it is evident that, supposing the earth spherical, they will belong to the great circle determined by the vertical plane, drawn perpendicularly to the meridian in question, and which, on the earth, answers to the celestial circle, named *first vertical*. The parallel soon separates from this circle, which it only touches at the point where it cuts the meridian. In a spheroid, the curve perpendicular to the meridian has a double curvature, and an inquiry into its properties has occupied several geometers [z].

The meridian and its perpendiculars being the lines most

[u] R. Vaugondy, Instit. Geogr. 324. Puissant, Topogr. 133.

[x] Fournier, Hydrogr. l. xiv. ch. 30.

[y] Cassini, Acad. des Sciences, 1745.

[z] Mém. de l'Acad. des Sciences, 1733.

easily traced by astronomical and geodesical operations, it is to the meridian of the observatory at Paris and to its perpendiculars that the points of the map of France are immediately referred; their latitudes and longitudes were only concluded *à posteriori*, and by calculation [a].

Properties of this projection.

To form an idea of the manner in which this projection represents the terrestrial spaces, we must observe, that the great circles perpendicular to the meridian, (supposing the earth spherical,) all cut each other at the poles of this meridian, and consequently converge towards each other, while, on the map, where the same meridian is a right line, they become parallel among themselves. It thence results that the portions determined by two circles perpendicular to the meridian are represented by rectangles of the same length, but broader towards the extremities. Thus their distances and their areas can be measured immediately on the map of France only by approximation; and though the extent in longitude is not considerable enough for the convergence of the perpendiculars to the meridian to induce an important error [b], we must be cautious in the employment of this projection, which is only excellent for the immediate assemblage of trigonometrical surveys. Several German geometers have calculated formulas and tables to render its use more sure, and correct its errors [c].

Spindle of the terrestrial globe.

It is to arbitrary developments of the globe that we must refer the construction of the *spindles*, which are traced on paper, to cover globes that are not very large. The surface of the globe is divided into 12 or 18 parts, according to the size of its diameter, by drawing meridians, of 30 to 30°, or of 20 to 20°. The space comprehended between two of those meridians, having very little curve in the direction of its breadth, may be considered as forming part of a cylindrical surface circumscribed to the sphere, accord-

[a] Du Sejour, Traité Analytique des Mouvemens apparens des Corps celestes, t. ii., and the Description Geometrique de la France, by Cassini.

[b] They extend in the extremities of Cassini's France to 150 toises in 40,000. Barbié du Bocage. Topog. Mem. du Depot de la Guerre, 1, 23.

[c] Zach, Correspond.

ing to the meridian which divides it into two equal parts. This meridian is developed, and by carrying perpendicularly (like ordinates) on each side the semi-breadths of the portions of parallels comprehended between the meridians which terminate the spindle, we obtain the form of the latter. Sometimes it is truncated at the two extremities at 15 or 20 degrees from the poles, and these two zones or spherical domes are traced apart, considering them as if they were flat. This process is only an approximative mechanism, which facilitates the fabrication of globes, and deserves no farther notice. Let us only express our wish that some able mechanician would invent the means of giving more exactness to the engraving of globes, at the same time that the advantage of the multiplication of copies is preserved.

BOOK VI.

Continuation of the Theory of Geography. Continuation and end of the Theory of Geographical Maps. Of the choice and assemblage of Details.

In vain would geometry have taught us so many and such ingenious methods of tracing maps in a manner conformable to the wants of geography, if we could only insert in these pictures of the globe incomplete images of the different countries. All our projections would then be only what the rules of perspective are to a sign-painter. It is the novelty, the exactness, and richness of details, which distinguish a learned map from those unformed sketches, the contrivance of which is confided to ignorance. To compose a good map, we must know how to choose, and to assemble the details which will form its merit.

Choice of projections of the scale.

The first object of consideration for the designing geographer is to determine the kind and the object of his map. Is it *general?* does it embrace a vast portion of the world? He chooses a large paper, and employs a projection such as the different modified conical projections, which hardly alters the configurations. Does he wish to construct a *map of the world*, destined for the studies of astronomical geography? He uses the horizontal stereographic projection. Is it to be applied to physical geography? He prefers the development of it on a single meridian, placing the new continent to the right, not to interrupt the connexion of the continents. In *special* maps, where an empire or province is traced, the choice of the projection seems more indifferent, because the defects of all the methods diminish when the map embraces only a small portion of the surface of the globe. Neverthe-

less there are advantages and inconveniences which flow from the nature of projections, and which we have indicated in the preceding book; there may be also one projection which, with respect to the paper, will oblige the geographer to admit into his map more countries foreign to his principal object than another; but it is essential to avoid such projections, because they diminish the *scale* of the map; that is to say, the proportion between the image and the object represented. Mariners who *point* their route on maps, say, instead of great and small scale, *great* and *small point*, an expression properly applied only to reduced maps.

The impossibility of admitting into a map, even of very great dimensions, all the details relative to topography, necessitates a choice among those details, which, however, it is impossible to subject to general rules. One map is destined to shew the political limits of states, and the boundaries of provinces, with their chief towns; another is destined to shew the chains of mountains and the branches of rivers; and these two classes still admit of sub-divisions. A *military* map is, in reality, only a perfect and detailed topography; the warrior should find in it every road in which he can advance, either with artillery, or only with his musket; every ford in a river, every defile by which he can turn the position of an enemy; in a word, these maps should exhibit all the localities which can influence his operations; the number of good military maps is therefore very limited. It is in great part to the excellence of those supplied by the *Depot de la Guerre*, that the French armies owe their successes. A learned geometer, deeply skilled in the art of war[a], had made a list of the French generals, in which he estimated their talents; opposite an illustrious name was often this note, *He is well acquainted with the map.* The importance of geographical studies for the leaders of armies was felt by the ancients, and the

Political and physical maps.

Military maps.

[a] M. Carnot. Comp. Zach. Corresp. Astron. i. 520.

Romans knew well, "that localities frequently influence victory more than courage and numbers [b]."

Other branches of government equally require maps, especially consecrated to a particular object. Those of the waters and forests, for example, should always be consulted as a beacon in cultivation; and in this respect the states of Germany have hitherto had advantages over France. What a military map is for the ground, *nautical* maps are for the seas; they even interest the physical geographer, as they represent, though very imperfectly, the irregularities of the bottom of those basins covered with water which occupy so vast a portion of the globe. The rocks, reefs, sand-banks, scattered through the seas, are sub-marine mountains and hills; and a complete knowledge of them would throw great light on the geography of the terrestrial mountains. Unfortunately nature seems to forbid the hope of our ever completing that part of geography. "Navigators," says a celebrated mariner [c], "can only answer for the routes they have made, or the soundings they have taken; and it is possible, that, on the finest seas they may have past *close beside* banks or shoals where there were no breakers (that is to say, whose existence was not betrayed by the foam of broken waves.") The maps of rivers present in detail all the branches of a stream, and all the circumstances of its course. They are comprised with nautical maps, under the general appellation of *hydrographic.*

Nautical maps.

There are also maps of botany, mineralogy, geology, and even of zoology, the object of which is to show the geographical distribution of the productions of nature [d]; there are some which their authors decorate with the name of *historical*, and which are intended to show the migrations of nations, and the changes of sovereignty [e]; finally, there are few objects, the reduction of whose relations of locality

Scientific maps.

[b] Veget. De Re Milit. iii. c. 26. [c] La Perouse, Voy. ii. ch. ii. p. 54.

[d] Ritter, Cartes Physiques de l'Europe.

[e] The Historical Atlas, by Kruse, in German, is the best work of this kind.

has not been attempted in the form of maps. But the composition of these sorts of tables is subject to rules derived from sciences foreign to geography.

All maps are not intended to advance our knowledge by the publication of new details, or by greater exactness. Public instruction requires *elementary maps*, the merit of which consists in rendering, in a faithful and complete manner, truths already known, and in which it were to be wished a system of engraving might be adopted, less elegant and less costly than what the refined taste of the public requires. The essential point in an *elementary atlas*, is not to display on a great scale maps full of details, and of minute exactness, but rather to exhibit, in a series of small but numerous maps, the complete assemblage of the principles of the science. Elementary maps.

After having duly reflected on his object, the designer has to collect and combine the details necessary to fill his map.

Good astronomical observations here hold, without dispute, the first rank; but how difficult is it to judge whether an observation be good! How many inconsiderate changes have been introduced into geography by the employment of longitudes badly observed or ill calculated! Above all, how many errors are owing to the careless use of the chronometer! We have indicated the different methods by which the astronomer assists in fixing the geographical positions of terrestrial places [f]; but the value of an observation does not depend solely on the goodness of the method; to appreciate it we must know all the processes, and all the circumstances, and submit these details to a minute criticism, and to careful calculations. In a word, we must imitate the example of Oltmanns, in his Researches on the Observations of Humboldt. It is in studying the work of this geometer [g], that geographers may learn all the rules of sound criticism with respect to astronomical data. The true geographer ought to be almost an astronomer. Thus we every Employment of astronomical observations.

[f] Above, b. 4.

[g] Voyage de Humboldt, part. astron.

where recognise that fraternal tie which unites all the sciences by rendering them necessary to each other!

The second and the richest source from which geographers draw the details of their maps, is triangulation; we have given an idea of it in speaking of the measurement of the earth by Picard [h].

Employment of geodesical measures.

When the position of a certain number of points has been fixed, either by astronomical observations, or trigonometrical measures, it is easy to connect with these points the particular plans taken on the ground, and which exhibit the localities in detail. But, as the art of drawing plans on the ground depends in great part on principles foreign to geography, we shall content oursleves with indicating merely some practical means employed by geographers for constructing a topographical map from partial surveys. The reader who wishes for detailed instructions on trigonometrical subjects, cannot do better than to have recourse to the excellent Treatise on Geodesy by the learned and ingenious Puissant.

When we wish to construct a map by connecting together plans taken separately, it is necessary that each of these plans should have at least two points in common with that to which it is to be joined; or, which comes to the same, there must be a line determined both in size and position in one which can be applied to a similar line in the other. Then, by drawing on the paper destined to form the general plan that *directing line*, so that there may be on each side a space proper for comprising each of the plans, it will be easy to refer to this general plan all the points that have been determined on the partial plans, by attaching them, by triangles, to any two points taken on the directing line, or combining them with any point, the position of which has been fixed. If there is to be a reduction, as almost always happens, the triangles of the topographical plan must be made similar to those formed on the basis of the surveys; but so that the sides of the

[h] Above, b. ii.

former may be to those of the latter in the relation which the reduction to be made requires.

When the sheets of the surveys are *orientées*, that is to say, when on each sheet the direction of the meridian, either the true or the magnetic, has been marked, the points of each plan are referred to the meridian, and to a perpendicular brought on that line by a point common to two contiguous plans. The distances are measured from all the points to each of these right lines parallel with the other; and, either preserving these distances as they were found, or reducing them in the relation required, they are brought on the meridian, and the perpendicular drawn in the topographical plan to represent those which are common to the collected plans. This method of constructing graphically the general map after the plans of the surveys, has given rise to a mechanism of reduction known by the name of trellis; it is very convenient for bringing together the details of the map, but should not be used for fixing the position of the principal points. This operation consists in dividing the plans that are to be united in squares, by lines parallel and perpendicular to that which is common to those plans; the more these squares are multiplied, the better we perceive the place occupied in each square by the points and turns contained in it, the more easy also it is to refer them to the corresponding squares traced on the plan of reduction or of assemblage. Fig. 46. represents this operation. The leaves ABCD, EFGH, having for common lines the right lines CD and EF, are divided into squares, the sides of which are parallel and perpendicular to those right lines; the plan of assemblage *a b f e*, is divided in the same manner, with respect to the line *c d*, which represents the common right line, but the sides of each square are the halves of those of the plans ABCD, EFGH, so that the objects marked on these leaves are reduced on the plan of assemblage to a half of their former dimensions, and to a space which is only the quarter of that they first filled. To reproduce the design traced on each of the primitive plans, either it may be imitated at sight, in the correspond-

Reduction by trellis.

ing squares of the leaves ABCD, EFGH, or else, for more exactness, marks are made on each of the sides of the latter, and transferred to the others. If we wish to preserve exactly the designs that are to be copied, we may place upon them a very smooth piece of glass, and of equal transparency, on which squares are traced with a diamond, and afterwards two perpendicular lines are made to coincide together on those which are to serve for the assemblage of the collected plans, or on the points which determine them.

Chorographic maps.

After having thus formed the topographical plans by the assemblage of the various plans of the surveys, chorographic maps are formed from them, not only by assembling the plans, but by submitting them likewise to the laws of the projection that has been adopted. For this purpose, the meridians and the parallels are traced on those plans in right lines, as those circles are when only a portion infinitely small is considered. The corresponding quadrilaterals are also described on the frame of the map to be constructed, but conformably to the laws of the adopted projection; there is then nothing farther but to design in these quadrilaterals what is contained in the squares comprised between the meridians and the parallels of the topographical plans. If we wish for extreme precision, we take, with respect to the sides of the squares, the distances of the principal points inclosed in them; these distances are converted into subdivisions of the degrees of longitude, and similar ones are taken afterwards, setting out from the parallel and the meridian contiguous to the corresponding quadrilaterals on the map.

Of plans not *orientés*, and without a scale.

Two circumstances may stop the geographer in this operation. It may happen that the topographical plan may not be *orienté*, or having been so by the direction of the magnetic needle, only we do not know what was the declination of the compass at the time when the plan was taken and reduced. This element may be supplied when the plan contains two points, of which the respective position is known, for, by joining these two points by a right line, we have the angle which

this right line makes with the meridian, and, consequently, we may fix its place with respect to the meridian, or construct, by means of the given angle, the meridian of the plan. One may recover also, by similar means, the scale of a topographical map which is wanting; for, knowing the distance of two points of this map, we have only to divide the line which joins those two points into parts proportional to the itinerary measures contained in this distance; then it becomes the scale of the map, and shews the respective distances of all the other points.

General maps.

Chorographic maps are reduced into general maps by a process analogous to that we have just explained; we bring on the quadrilaterals formed by the meridians and the parallels of the general map, what is contained in the corresponding quadrilaterals of the chorographic maps we wish to assemble. But here the necessity of *geographical criticism* appears; here it is that the designer, quitting the humble part of a copyist, should, by his knowledge and researches, and especially by his intelligence, supply the imperfections of topographical data. Sometimes it is errors he has to correct, sometimes deficiencies to fill up; most commonly these two inconveniencies are combined together.

Correction of errors of topography.

It may happen that, in the topographic plans employed in the construction of chorographic maps, there may be errors common to all the points, as distances too small or too great in the same direction, and these errors may have been accumulated on the chorographic maps, and afterwards on the general map; the great spaces which it represents are then either considerably narrowed, or considerably lengthened, without the geographer himself being able to perceive it. In this case, the geographer will connect the details of the general map with the different points, the latitudes and longitudes of which are known by astronomical observations; these points determine on the map spaces into which the intermediary details will necessarily fit, sometimes the excess or defect that is found may be attributed to the imperfection of the mechanical processes employed for the as-

semblage of the maps; but then there is no other way but to divide the differences among all the points of each partial plan, which will render the errors less sensible.

Employment of itinerary distances.

The geographer unfortunately is but too often deprived of astronomical observations and trigonometrical surveys; there are only a few countries, as France, England, Denmark, Holland, and Hungary, which have been surveyed trigonometrically in their whole extent; there are still some European provinces where no astronomers have been. Geography is obliged therefore to have recourse to *itinerary distances*, always very difficult to estimate in a rigorous way, even when we know exactly the value of the measures in which they have been calculated. This science is as yet very little advanced, either on account of the immense number of measures to be compared, or on account of the variations to which they are subject, or, finally, with respect to many ancient measures, because the authentic modules are wanting [i].

Valuation of measures.

We have already seen that there are various opinions on the manner of estimating the *stadia* of the ancients, and that it is still doubtful if they should be considered as astronomical modules or local measures. We find in the ancients one passage in three which does not allow us to admit the first supposition, unless by adopting the most violent and innumerable corrections [k], or by the admission of an improbable mixture of different stadia; in the second hypothesis, which to us appears preferable, we do not yet perceive the basis from which to set out; we are on the right road but surrounded with profound darkness. However, this obscurity is better than the false glimmer of an hypothesis void of proof; and, besides, why should we be surprised at the

[i] Traité des Mesures Itinéraires des Anciens, par d'Anville. Observations, &c. par Gosselin, en avant de la traduction Française de Strabon. Traité des Mesures, par Romé de l'Isle. Métrologie constitutionnelle, par Paucton. Traité des Monnaies, des Mesures, &c. par Gérard Kruse, en Allemand. See the Tables at the end of this Volume.

[k] See the Notes of the French Translation of Strabo.

doubts in which ancient metrology is enveloped, when we know that even modern measures present cases in which it is difficult to reduce them? Undoubtedly we know exactly the relations of the measures most commonly used in capital towns, and cited in the works of the learned: we know, for example, the value of the English mile, and of the nautical mile, the degree of the meridian containing 69 of the former and 60 of the latter; we know also that the English foot, being equal to 0,9384 of the French foot, is 11 inches 3 lines, 1, and that the yard used in England for measuring short distances is three feet English; we consequently conclude that the yard represents 33 inches, 9 lines, 3 of France. Similar reductions give the means of converting into each other the measures generally in use in great states; but there are besides, in the provinces, local measures little known, and with respect to which multiplied researches must be made to obtain their relation with the others, either by comparing their components with the best fixed unities, or by setting out from some distance valued in local measure, and known in geographical measures. In France, for example, nothing formerly varied more, than the length of a league between one province and another. The perch even, which serves for surveying, was sometimes 22 feet, sometimes only 18. The new metrical system will prevent any such confusion in future [1].

Tracing of a nautical route.

When we know the value of the measures in which an itinerary is conceived, the direction of the route is marked after the points of the compass. When we have the length and the direction of a route, setting off from a point, the position of which is given, we very easily find that of the point where this route terminates. In the first place, when the route is not considerable, one may, in the space it traverses, neglect the curvature of the earth, that is to say, con-

[1] Since this was written, M. Uckert, a professor at Gotha, has attempted to prove, in a learned manner, that the ancients only used *one* kind of *stadium*, that of Olympia, and that all the differences and contradictions in point of measures proceeded from the imperfect means they were obliged to employ. Ed.

sider the meridians as parallel with each other, and, consequently, the points of the compass as right lines. To construct this route on a flat map, it is then sufficient to draw, through the *point of departure*, a line which may make with the meridian of this point an angle equal to that which the point of the compass followed gives, and to carry on that line a number of parts of the scale equal to that of the itinerary measures gone over: the point where these parts terminate will be the *point of arrival*. Calculation may also be substituted for construction; if from the extremity of the route gone over we bring down on the meridian, which passes by the other extremity, a perpendicular, a rectangled triangle will result, in which the part of the meridian intercepted between the point of departure and the perpendicular brought from the point of arrival will indicate the distance of these points taken on the line north and south, or the difference of latitude expressed in itinerary measures; which are afterwards reduced, according to their value, into degrees of the meridian. And the perpendicular will express the distance of these same points taken on the line east and west, which is confounded in this case with the difference of longitude expressed in itinerary measures. If we wish to convert it into degrees, we must divide it by the number of those measures which a degree of the parallel of the point of departure ought to contain, or, if we wish for still more exactness, by the number of measures comprised in a degree of the parallel which holds the middle between that of the point of departure and that of the point of arrival. All this operation is nothing but dividing the number of the itinerary measures by the cosines of the latitude of the mean parallel.

To find the direction of a route.

A second question may present itself, in the case where the direction of the route is not known; the latitude of the point of arrival is then substituted for it. The construction on the flat map consists, in this case, in drawing through its latitude the parallel of the point of arrival; in taking on the scale of the map the number of measures assigned to the distance gone over, and to describe with this

distance as radius, and from the point of departure as centre, a circle which will cut in the point of arrival the parallel previously drawn. If we wish to resolve this question by calculation, we must convert into itinerary measures the difference of latitude between the point of arrival and the point of departure; we have then in the rectangled triangle formed by the meridian of the point of departure, the perpendicular let down from the point of arrival and the route, two known sides, namely, the length of the route, or the hypothenuse, and the part of the meridian comprised between the point of departure, and the perpendicular of the point of arrival: by calculating the length of this perpendicular, we find the distance of the points of departure and of arrival, taken on the line *east* and *west*, whence we conclude, as above, the difference of longitude.

Spherical curve of a route.

When the route gone over is of a considerable length, it becomes necessary to take the curvature of the earth into account. The construction of the two preceding problems requires, with respect to the reduction of leagues gone over in the direction *east* and *west*, in degrees of longitude, the employment for the tables for measuring latitudes, which contain the results of the trigonometrical calculation, by which the case may be resolved[m]. For the first

[m] We have seen above, (p. 120.) that it is only by the help of the integral calculus that we can arrive at the exact construction of the tables of increasing latitudes; but geographers commonly make use of a very simple approximative means to reduce the curve to a right line, by considering the route gone over as divided into parts small enough to be regarded as right lines. In fact, since the points of the compass cut all the meridians under the same angle, we may conceive that, through the extremities of all these subdivisions, may be brought meridians and parallels; thus will be formed, on each of these parts, a rectangled triangle, in which the sides of the right angle will be the differences of latitude and longitude, and the part of the route gone over will form the hypothenuse. But rectilinear trigonometry supplies the means of calculating this triangle, since we know the hypothenuse and an angle. Let ABC, *Fig.* 47. be one of these triangles; we shall have by the principles of rectilinear trigonometry, AB : AC :: 1 : cos. BAC; whence we shall conclude AC = AB cos. BAC. Now, as the angle BAC is the same with respect to all the meridians which traverse its route, each difference of latitude, from one small triangle to

question in which the direction of the route is known, after having obtained, as above, the latitude of the point of arrival, we must take, in the table of increasing latitudes, the difference of the numbers which answer to this latitude, and to that of the point of departure; it must be multiplied by the tangent of the angle corresponding to the point of the compass, and the result will be the difference of longitude expressed in minutes of a degree. In the second ques-

the other, will offer the same factor, and the sum of all these differences, which is evidently the total difference in latitude, between the point of departure and the point of arrival, must be *equal to the sum of the portions of the route*, that is to say, *to the total length of this route, multiplied by the cosine of the angle which its direction forms with the meridian.* We shall be in the same case as when we neglect the curvature of the earth, and the same means must be employed to reduce the route to degrees.

If we now wish to know the difference in longitude corresponding to B C, it is by means of the latitude AC that we can calculate it. We shall have the proportion AC : BC : : 1 : tang. BAC, from which we shall conclude, BC = AB tang. BAC. To know how much this difference makes in aliquot parts of the equator, we shall design by L the latitude of the parallel under which is situated the point A, and we shall have this proportion, BC : x (or to the corresponding part of the equator) : : cos. L : 1, which we can transform into this; $x = \frac{BC}{\text{cos. L}}$, and if we put in the place of BC its value, which we found above, this proportion will result: *the difference in longitude* $= \frac{AC}{\text{cos. L}} \times$ tang. BAC. We shall obtain, therefore, the sum of all these small differences of longitude resulting from each part of the route, if we multiply by the constant factor tang. BAC, the sum of all the values represented successively by the factor $\frac{AC}{\text{cos. L}}$, changing for each portion of route.

Let us now conceive all these portions so small that the difference AC' is equivalent to 1' of a great circle of a globe, and let us observe that $\frac{1'}{\text{cos. L.}} = \text{sec. L.}$ we may substitute to that expression this : *the difference in longitude* $= 1' \times$ sect. L. tang. BAC; then we shall find the sum of the factors $1' \times$ sect. L By adding all the secants from minute to minute, from the latitude of the point of departure to that of the point where the route terminates.

As the arc of 1' is not rigorously a right line, the process is only approximative; if we wish to render it more exact, by taking the secants from second to second, we should fall into extremely long and fastidious operations. It is to the integral calculation therefore we must have recourse. See the excellent Traite de Navig. of M. Dubourguet, b. i. chap. 3 and 4, &c.

tion, the angle of the point of the compass is not given; but it may be calculated by the difference of latitude reduced into leagues, and by the course, which are then the data; the difference of longitude is afterwards concluded by the rule first indicated. Supposing, for example, that a vessel set out from a point situated at 42° 3′ of north latitude, has gone 252 marine leagues to the *north-east ¼ east:* we remark in the first place, that this point of the compass forms with the meridian, on the east side, an angle of 56° 15′, and we thence conclude that the route answers, on the line north and south, to 140 leagues; which gives 7° of difference towards the north. As this difference is of the same denomination as the latitude of the point of departure, it must be added to the latter, to obtain that of the point of arrival, which, consequently, must be 49° 3′. We then look, in a table of increasing latitudes, for the number which answers to 49° 3′, namely, 3386,7; then for that which answers to 42° 3′, and which is 2785,8, and we take the difference = 600′ 9; to the logarithm of this difference is added that of the tangent of 56° 15′, the angle of the point of the compass, and the result which answers to 899′, or to 14° 59′, is the difference of longitude towards the east.

Errors of itinerary distances.

These rules can only lead to exact results, in so far as they are applied to data exempt from error. But this is not always the case, especially in ancient geography, and even in modern travels down to the 16th century. In the first place, the direction of the route, often ill observed by land, is still more so at sea. If it has been marked according to the rising of the sun, the diversity of the seasons often renders it uncertain; if it be indicated according to the compass, it may be affected by the variation of the needle, which has not been always observed. Navigators were exposed to another cause of error. They did not allow for the angle, which the real route of the vessel forms, with the direction of its keel, wherever the vessel receives the impulsion of the wind sideways; for, in this case, a part of this force tends to push it out of this route, while it is kept

in it only by the action of the rudder, and by the great resistance which the surrounding fluid opposes against its sides. This angle, rather difficult to determine, was generally neglected by the navigators of preceding ages. There are also great uncertainties in the measure of the distance gone over. The ancients were in the habit of reckoning it by the number of days of a march, or of a voyage, and we have seen, in the history of geographical discoveries, how difficult it was to fix the value of those days, which, expressed in different or vague terms, must always vary according to times, seasons, regions, the mode of travelling, and the size and form of vessels. Even the most learned combination of all these circumstances, only procures us mean values the more probable, as a greater number of sure and authentic facts have been combined. Geographers have thought that by studying and estimating the sinuosities of roads, in countries intersected by mountains or by considerable streams of water, and also in plains, we might arrive at general principles on the augmentation of length which these windings occasion, and which of course must be subtracted, if we wish to reckon the distances on the same line. The Arabian geographer, Al-Biruni, concluded that, in the East, itinerary distances should in general be reduced a fifth [n]. D'Anville finds, on the contrary, that in Italy and Egypt, and, in general, in the world known to the Romans, we need only deduct an eighth [o]. The very nature of the question evidently renders a general solution impossible.

Sinuosity of the route.

Value of days of march.

We may say the same of the discussions which have attempted to fix the value of days of marching and sailing. When Herodotus [p] fixes a day's sailing, during the day, at 700 stadia, while Scylax [q] only admits 500, it may be right to consider this difference as merely the result of the employment of stadia of a different value; that of Scylax

[n] Al-Biruni, ap Edw. Bernards, de Ponder. et Mens.

[o] D'Anville Consider. sur la Geog. 44—47. [p] Herod. iv. 46.

[q] Scylax Peripl. p. 30. ed Vos.

being probably very near the stadia of 883 to a degree, and that of Herodotus, being the Egyptian stadium of 1111 to a degree, ancient measure. But the Greek geographers themselves have expressly informed us, that their days of navigation varied according to the places, times, and means employed [r].

The combinations that have been made of such maritime distances [s], should therefore be considered only as approximative, and in no respect superior to the data which result from the physical and historical descriptions of countries that have been visited.

Errors of estimation of navigation.

How, indeed, could we expect to fix the value of the ancient days of navigation, when it is notorious that we hardly know that of the navigators nearest our own times? The ordinary means for estimating distances at sea, are still subject to much uncertainty. To estimate the distance gone over by a vessel, requires a knowledge of the effect of currents, which act at once on the vessel and on the *log*, which sailors throw into the sea, and which serves as a fixed point for them, from which they count how much they advance in a given time, commonly half a minute. This motion is measured by means of a cord divided by knots, the interval between which answers to the 120th part of the hour. But when the vessel and the log are subjected to the action of the same current, the distance by which the vessel exceeds the log, only indicates the relative quickness of the ship with respect to the current; and we have still to determine the velocity which this current impresses at the same time on the log and on the vessel. Such is the principal origin of the differences, often very considerable, between the place where pilots think they are, according to the estimate of their routes, and that where the vessel really is. In consequence of these errors, the lands discovered by the Magellans, the Mendanas, the Quiros, have been so ill placed in longitude, that geographers have had great difficulty to ascer-

[r] Ptolemée, Geog. i. c. g. Marcian Heracl. p. 67, (tom. i. Geog. Minor.) See the authors cited in the tables of this volume.

Example drawn from Solomon's Isles.

tain them. We have seen, if we may say so, *Solomon's* isles, so remarkable for their beauty and riches, and for the detailed description of them by their first discoverer Mendana, floating through near a quarter of the circumference of the globe. None of the navigators who went over these parts after him, beginning with Quiros, his companion, and who followed him immediately, could break the charm which seemed to forbid to mankind the access to a land which the imagination, stimulated by obstacles, clothed in the most brilliant colours. More sober minds began to doubt their existence; when Dalrymple and Fleurieu showed, that they must be identical either with the New-Britain of Dampier, or with the land of the Arsacides, and the adjacent isles visited by Bougainville and Surville. In the latter hypothesis, the latitudes first assigned to them were not very exact; but the currents which go from east to west, in the great ocean, had accelerated very much, without his being able to perceive it, the vessel of Mendana, who reckoned himself to be only 1500 Spanish leagues, or about 1700 marine leagues of France, from the coasts of Peru, when he was really near 2,400.

Since the frequent observation of longitudes has permitted a comparison, in many points, of the distance estimated with that really gone over, navigators who have sailed round the world, have collected and multiplied very important data on the velocity of currents in the various seas of the globe [t].

Employment of ancient maps.

Astronomical observations, trigonometrical surveys, and itinerary distances, are the three elements of every map entirely *original*. But, commonly, we do not find these three elements completely united, especially for countries remote from Europe; we are therefore reduced to repeat what other geographers have published with respect to the parts on which we have no new information. Here again the geographer requires great sagacity.

[t] Voyage of Captain Marchand, drawn up by Fleurieu.

When he has established the agreement of the measures, or scales employed in the various maps which he wishes to analyse and discuss, he is enabled to construct a scale for those that have none, provided the latitude and longitude of any point whatever of those maps be known to him, either immediately, or by their distances from given points. He can, consequently, compare, by the positions which they assign to those same places, the maps which represent the same regions; and this manner of proceeding, is at the same time the surest and most commodious, as it facilitates the observation of the differences resulting from projections. If the geographer finds the same point placed under different longitudes and latitudes in several maps, to appreciate these different data, he must examine how these maps present other essential circumstances; it is then that he should compare the respective situations of places with respect to determined astronomical points, and that he ought to scrutinize minutely the configuration of shores, the trace of rivers, of chains of mountains, and of high roads, and the indication of the limits of territory. A similar examination teaches him in what his maps differ, and in what they agree; he is left to choose between them. The latitudes less difficult to observe than the longitudes, are generally better fixed on maps, drawn according to the relations of travellers of rather ancient date. The common defect of maps, anterior to D'Anville, is to augment much the distances of places in the direction *east* and *west*. The farther the points in question are from the principal meridian, according to which the longitudes of the others have been determined, the more considerable these errors become. This strikes the least skilful eye in the maps of Ptolemy, with respect to the differences of longitudes which they give between Alexandria and the other towns situated on the borders of the Mediterranean. The absurd opinion which places Seria in China, and other similar errors, are only due to the false extension of Ptolemy's maps in the direction of longitude. But we are indebted to this same fault, repeated in

Comparison of maps.

Common defect of ancient maps.

the maps of the middle ages, for the fortunate error on the extension of the islands of Japan to the east, which gave Christopher Columbus courage to cross the Atlantic.

The maps of Sanson, Jaillot, and others, formed at the end of the 17th century, and admired by some bibliomaniacs, likewise dilate all the countries in the direction of the longitudes[u]. Such maps, however, afford useful materials, when the positions are corrected in the direction *east* and *west*, by shewing proportionally to the distance from the principal meridian, the differences between the longitudes which these maps give, and those which result from the new determinations.

Too often the geographer has no decisive reason for choosing between the different positions assigned to the same place by several maps. Surrounded by uncertainties, he has only then to take the middle, according to the rules of arithmetic, between the latitudes on one side, and the longitudes on the other, as they are given by the maps. He then places, on that which he wishes to construct, the principal points, according to a reduction, the process of which it would be superfluous to indicate. Sometimes the geographer is obliged to compare maps of detail by the distances they give between the same places, distances which have been most frequently the elements for the construction of those maps, and which, for this reason, it is often essential to ascertain. He may then choose, on each of those which he wishes to compare, two corresponding points, determined with exactness, and from which he can measure the distances to all the others. All these distances being brought to one single scale, he traces on the paper a line, which represents the distance from the two principal points, according to the scale he employs. On this line, serving for base, he describes, with the distances drawn from each map in particular, triangles, the summit of which answers to the place assigned by each of these maps to the

Combination of discordant distances.

[u] D'Anville, Considerations, p. 11, 99.

points he examines. Two different determinations of the same point being joined by a line, the mean position will be found on the middle of this line. Three determinations give a triangle, and a greater number constitute a polygon. In these cases, the mean position is found by seeking the centre of gravity of the area of this polygon, its angles being considered as masses equal to unity. This is not the place to give the demonstration of this rule, founded on the principles of statics, and on the theory of mean values; we may, however, be allowed to remind the reader that, in the case of a triangle, the centre of gravity is at the intersection of the right lines, drawn from the summits of two angles, to the middle points of the opposed sides. This easy construction only is wanted in the most ordinary case, when there are only three determinations. The mean distances from one point to two others, the position of which is given, being once fixed, it is easy to determine the latitude and longitude of this point, and to place it afterwards, by their means, on the map to be constructed, whatever be its projection. When the combined points embrace a space so little extended that the projection is not sensible, the labour is abridged by transporting to the map, by means of the *trellis*, the results of these comparisons.

The mathematical elements of a map being determined, it still remains to introduce into it the historical, political, and physical details, of which its extent and object render it capable.

Geographical signs.

The objects of common geography require the employment of only a small number of signs, easily understood, and the sense of which was explained by ancient geographers, in a legend placed on one of the sides of the map; a custom which ought to be resumed in elementary atlasses. These signs indicate the position of places, and are modified according to the importance of these places, and the rank which they occupy in civil, military, or ecclesiastical government. When we wish to measure distances on a

map, we must remark the very small circle or cipher, which is either adjacent to, or inscribed in each of those signs, because it is the central point of this circle which fixes the geographical position of the place. When the map descends into a great detail, the principal features of the plan of large towns are expressed, and then care should be taken to mark on this plan, that point to which the geographical position is referred. A simple line shews the course of small streams, and the two banks are indicated separately, only when the dimensions of the bed of the river can be appreciated by the scale of the map; which is most frequently at the mouth, or at places where the stream is dotted with islands. The sea shores are indicated by a very clean line, bordered with hatchings. In geographical maps, these hatchings, exterior with respect to the land, may be conceived to represent the undulations of the sea on the coasts; while, in marine maps, the hatchings done on the land, paint to the eye the acclivity of the coast. Navigable canals are represented by straight lines joined angularly, which distinguishes them sufficiently from natural streams of water, indicated by undulating lines. Roads are often marked by two fine parallel strokes, sometimes by simple lines, continuous, or punctuated; the latter, however, are most commonly reserved for marking the limits of states and their provinces, and for this purpose the size and form of the points are varied.

Illumination.

To render more striking those political divisions, which so often form an absurd contrast with natural limits, the monotony of the engraving is relieved by varied colours. Some German geographers have preserved the ancient French method of spreading the same tint over a whole region, which they wish to distinguish from others. This mode of illuminating, has perhaps less elegance than that used now in France; but it has the advantage of shewing better the extent of regions, and the form of their limits: it should be adopted in every elementary atlas.

Some teachers think also, with reason, that the old manner of indicating the towns by little towers, multiplied and

modified according to the rank of the place, was preferable in general maps, to the mode prescribed in the *Depot de la Guerre*, which consists in representing every object on a geometrical plain [y]; a system, the rigorous application of which, in our opinion, should be reserved for topographical and chorographical maps.

Orthography of names.

We cannot pass over in silence a point of which, among the French, D'Anville [y] alone felt the importance; this is the orthographical exactness of the names in maps. Good sense dictates the rule of writing each geographical name, as near as possible to what is used in the country it belongs to, and to what is pointed out by sound etymology. A corrupted orthography should only be admitted when the right one would not be understood by the generality of readers. Thus, it is certainly wrong to write *Natolia*, instead of *Anatolia*, which is required by the Greek etymology, or *Dannemarck*, with the German consonant *ck*, in place of *Danemark*, which is conformable at once both to the genius of the French tongue and to that of the Danish. It is thus that a certain number of geographical denominations might be brought back to the true orthography. However, a much more considerable number would not admit of this reform. It would be easy, for example, to introduce *Ireland* instead of Irlande; but, in France, *Scotland* could never be substituted for Ecosse, as the first name would be unintelligible to most French readers. It is true, that it is rather difficult to practise this rule, with respect to names drawn from languages in which a different alphabet is employed from that adopted in Western Europe. Such is the case with the Russian, Persian, Arabian, Indian names, and others; also with the Polish, in which several letters of the alphabet have a different value from what we give them. This is not the place to examine all the expedients that might be tried to establish, once for all, a geographical or-

[y] Mem. Topogr. et Milit. [y] D'Anville, Consid. sur la Geogr. p. 61, 63.

thography, not absolutely fixed, (which would perhaps be useless,) but at least easy to follow and comprehend [a].

Signs of physical geography.

The physical part of a map requires attention to be paid to certain other circumstances. It is desirable to know if a country is covered with plains, or is rough with mountains, naked or wooded, dry or marshy. Designers have introduced signs, either conventional, or of the nature of pictured representations, to express, on trigonometric surveys, and topographical plans, these different circumstances, which, joined with the climate and the laws of meteorological phenomena, determine the *physical geography* of each country. It is sufficient to cast one's eyes on plans of this kind, to discover the signs employed in them; they are all conformable to the rules of bird's-eye perspective; thus the parts more or less strongly shaded, represent slopes more or less steep, on which the light is lost the more they approach the vertical position. Geographical maps are less calculated to admit of this improvement, especially with regard to mountains; for the scale of those maps is necessarily too small to admit of expressing on them, in just proportions, the innumerable inequalities of ground, from the highest chains of mountains, to hills of the lowest order.

Representation of mountains.

Formerly, mountains used to be represented by slight elevations in profile, which supposed the eye of the spectator to be in the plane of the map. At present, they attempt to represent in a bird's-eye-view the chains and groupes of mountains, and even the peaks or insulated points which repose in general on elevations more or less considerable, but the whole extent of which presents contours that determine the form of valleys [b]. The new method would undoubtedly be preferable, if one could preserve a just proportion between the different elevations, and if we possessed all the necessary information for determining, point by point, the level of the ground. But, as long as these elements are

[a] Comp. Langlès, Préface du Voyage de Norden; Volney, sur l'Alphabet Russe, &c.

[b] Memorial Topographique et Militaire, cah. v.

wanting, the new method will be as arbitrary and illusory as the old one appears unnatural and unsatisfactory.

The partisans of the plan of representing mountains by a bird's-eye-view, shew us the maps of D'Anville, and exclaim, "How vague and insignificant are these mountains, marked with insulated points! All that we see is, that the country they occupy is mountainous; one might as well write down: *there are mountains here;* nothing indicates the course of chains, their various sinkings, and their connexions, either with each other, or with the islands which form the summits of the chains of *submarine mountains*, or which traverse the basin of the sea." But, in the first place, there are many other maps besides those of D'Anville, in which the mountains, though expressed in profile, please the eye and satisfy the mind. And we ask, in our turn, if geography has really gained by the admission of all these pretended chains, either terrestrial or *submarine*, which M. Buache, sen. has created, by supposing arbitrarily that all the basins of rivers are separated by considerable heights.

Method proposed for exhibiting levels.

The pretensions of topography have been pushed still farther. A geographical engineer, M. Dupain-Triel, has published a method, by which a geographical map may be made to indicate the elevation of each point of the ground. He observes[c], that if we join by a line drawn on a marine map, all the points at which equal soundings are marked, this line would give the contour of a section made at the bottom of the sea by an horizontal plane at such a depth below the surface of the fluid, as is expressed by the number of measures contained in the sounding. From this observation, just in itself, he thinks he may deduce a principle for representing *geometrically* the configuration of the surface of a country. This consists in tracing on the

[c] Dupain-Triel, Carte intitulée, Méthode nouvelle pour exprimer sur les cartes les hauteurs, etc. avec un mémoire de M. Du Caila. Paris, 1784. Id Carte de la France, où l'on a essaye, etc. An. vii.

map to be constructed, lines which pass through points placed at the same level, or at the same height, above the surface of the sea; lines which would become successively the boundaries of its waters, if it rose, by any cause whatever, to the level they occupy; as the lines which join equal soundings would become in their turn the shores of the sea, if it sunk by the number of measures marked on those soundings. The heights of these lines or *horizontal sections of the ground* could be graduated, according to the scale of the map and the steepness of the slopes. On a specimen of maps of France executed according to this plan, M. Dupain-Triel traced in parts almost flat, and near the sea, a line passing through the points elevated 10 toises; then another passing through those elevated 20, and so on from 10 to 10 toises. We see these lines, at first pretty distant from each other, become closer in proportion as the country rises more rapidly. Round the insulated mountains, the line of level, which is marked only for differences of 50 toises, and even 100, come closer the more the slopes are steep. Table-lands are indicated by lines of level, which turn round them. Finally, if we conceive lines which cut the lines of level at right angles, we shall have the *lines of the greatest declivity*, or those which follow in their descent the waters spread on the sides of mountains.

Value of this method.

Though this method of M. Dupain-Triel is not new, having been already proposed by Ph. Buache and others [a], it undoubtedly merits some attention. It is evident that it furnishes descriptive geometry with means for resolving problems on the succession of table-lands, the intersection of slopes, and the intervention of basons; problems interesting in the construction of roads and canals. It might offer the means of collecting and putting within the reach of every body a multitude of levellings and observations, made by military and civil engineers, on the heights of mountains, the results of which are confined to the portfolios of

[a] Mem. de l'Acad. des Scien. 1752, p. 399; 1753, p. 586; et 1756, p. 109.

government: finally, the advantage to be derived from it would excite travellers, and philosophers residing in all great towns, to multiply barometrical observations in order to determine the respective heights of the places where they are made. But, till the elements of such a map are more numerous and more authentic than those which we possess, its execution would only serve to give an air of reality to systematic ideas that are very uncertain. At all events, the confusion which would result from this multiplicity of lines, would prevent any object of political or historical geography from being clearly designed on these maps. We must therefore consign all inventions of this kind to maps, specially consecrated to physical geography, in the same way as the details of hydrography are reserved for nautical charts.

BOOK VII.

Continuation of the Theory of Geography. First sketches of Physical Geography. General forms and distribution of Continents and of Seas. External configuration of Mountains, Valleys, Plains, and Coasts.

HAVING considered the earth in regard to its dimensions, we must now study its PHYSICAL characters. This part of our work, which is perhaps the most interesting of all, will necessarily be the most imperfect; because a good system of physical geography, can only be the gradual work of many successive ages.

General views of physical geography.

This science, before it can make advances to maturity, requires a continual series of observations, both repeated and varied, made in every part of the world, and so combined, as to leave no interval unoccupied.

On the other hand, it is not with natural geography as with mineralogy, with chemistry, or with botany. Ingenious arrangement, and exact and methodical classification, are not very applicable to it, and for some time would only retard its progress, by loading it with a display of illusory notions. Mountains, valleys, waters, climates, and tracts of country, present themselves to the eye under very complicated and irregular appearances, which it is much easier to describe than to bring within exact definitions. The grandeur and majesty of nature, defy the subtilty of our combinations, and the littleness of our rules.

The spirit of physical geography, unquestionably rejects vague and incorrect language; but at the same time it cannot obviously be susceptible of the precision of terms, which belongs to mathematics or chemistry. What a striking dif-

ference is there between the winding, or the abrupt outlines of our mountains, and the regularity of geometrical figures? What an abuse has been made of the appellations *pyramidal*, *conical*, and others of a similar kind? How often has the term crystallization been employed to conceal the insignificance of a shallow remark. This famous word, like the sword of Alexander, has enabled many to cut knots which they knew not how to untie. In the cabinets, almost every thing is crystallized; in nature, almost every thing is irregular in its figure.

Even those objects which strike the eye most, are very difficult to be reduced under general terms. We commonly designate all elevations of land, that are the least prolonged, by the general name of *chains*. But it is certain that mountains more frequently form *groups* than chains; and even the most conspicuous chains are often composed only of a series of groups. Again, the same mass of mountains, which when seen on one side, appears to form a chain, is merely the declivity of a plain, more or less elevated. Travellers often give the name of mountains to the steep and lofty banks of rivers. It were endless to enumerate all the errors introduced by the mania of systematizing. There was a time when every black stone was considered as a volcanic production, and every circular pit as the mouth of a volcano.

Imperfect state of observations.

The other departments of natural geography are equally enveloped in darkness. What shall we say of that system of hydrology which is almost destitute of any information as to either the levels or the depths of seas? The direct observations upon climates, are somewhat more numerous, at the same time we must acknowledge, that our thermometers do not indicate the latent heat, the influence of which is so great and so universal; and, besides this, even the best observations upon climate often lose half their value from want of an exact description of the surface of the country. The common systems of Botanical geography, by simply copying the "*Flora*" of each country, are as incomplete as they are useless. It is necessary to distinguish the

elevation of the land, the quality of the soil, and many other local circumstances. If it appears more easy to determine the geographical relations subsisting between the different races of animals, now actually inhabiting the earth, what an abyss do we discover, when we attempt to examine the fossil remains of those genera which are now extinct, but which must once have peopled our planet? What revolutions have taken place! what mountains have been dissipated, what rocks decomposed! how many vallies have been filled up, how many lakes emptied of their contents, what inroads have the seas made upon the continent; what volcanic irruptions, what contests among the elements, slow or rapid, destructive or creative, must have preceded the actual state of our globe, a state which every where presents only the ancient ruins of an edifice, of the primitive proportions of which we are completely ignorant. Physical geography makes us feel the limits of our powers. We have ascertained the dimensions of the sun. We know the laws of gravity upon the surface of Jupiter. We have measured the elevation of the mountains of the moon: even the erratic comets seem to submit to the calculations of our astronomers. But the interior of that very earth upon which we walk, baffles our researches. We have never penetrated one two thousandth part of the diameter of the globe. Nay, even the very surface of the earth is not known to us throughout its whole extent. We shall perhaps for ever remain ignorant of the secrets which the two polar regions contain. Let us then endeavour to resist the seduction of systems, and detail with clearness, and above all with fidelity, the limited number of facts, which observation has collected, and which have passed the ordeal of sound investigation.

Physical divisions of the globe.

When we cast our eyes over a map of the world, we perceive, that the surface of the globe is divided into large masses of land, which we call *continents*, and great cavities, filled with water, which we term *seas*. As, in the parts covered with water, we observe small masses of land

Continents, seas, &c.

whose surfaces rise above it, which we name islands, so are there upon the continents small detached spots covered with water, which we call lakes. An island differs from a continent only in its dimensions; and in fact, we give the name of continent to certain portions of land, only because we have for a long time remained ignorant, whether a ship could sail round them, and because some physical circumstances have hitherto prevented such a voyage [a].

Many portions of the land and of the sea extend reciprocally the one into the other. If the sea penetrate into the interior of any continent, it forms there a *mediterranean* or inland sea, surrounded almost on all sides by land, and having only a narrow opening into the ocean. If the extent of such seas be less, and the openings larger, they are called *gulfs* or *bays*, two terms which geographical writers have wished to distinguish [b], but which customary language more frequently confounds. The still smaller portions of sea, surrounded as it were by land, and which afford a shelter for ships, are called *ports, crecks*, or *roads*. The first term means a secure asylum; the second is applied to places or ports of much smaller size, and which, when improved or completed by artificial aid, are styled *harbours*, and the roads afford only a temporary anchorage and security from certain winds. If, on the other hand, parts of the continents shoot into the seas, and are connected with the main land by only a small portion of their circumference, they are named *peninsulas*, whose figures often correspond with those of gulfs and inland seas. When such masses of land are attached to the continent by a greater extent of line than one-fourth of their circumference, they are not considered as peninsulas. Arabia, for example, seems to deserve this name, but the custom of applying it equally to the advanced part of India, west of the Ganges, offends against exact description. It is thus, that nature sports with our

Mediterranean seas, gulfs, &c.

Peninsulas, &c.

[a] Kant, Geographie Physique, ii. part. 1, p. 67. Edit. de Vollmer.

[b] Fleuriau, Introduction au Voyage de Marchant.

classifications. If the projections of land reach but a little way into the sea, they are called *capes, promontories*, or simply *points*. A natural canal communicating with the sea at both ends, and confined by two opposite shores, is called a *strait*: the reverse is an *isthmus*, that is, a tongue of land running between two seas, and by which two greater masses of land are united. Many other terms of a similar kind, being used only locally, will be defined as we employ them in the course of our work.

Let us now consider the surface of the globe under one general point of view. We perceive, that it consists of one vast ocean, in which a great number of *islands* are placed, whose size varies from that of the most colossal to the most minute. Two of these islands are termed continents; that which is inhabited by the oldest civilized nations is called the *old continent*, and contains three divisions of the world, namely, Asia, Europe, and Africa, while the whole of the new continent is comprised under the name of America, though nature has divided it into two distinct peninsulas, one of which ought in strict historical justice to be called Columbia. In the midst of the most extensive mass of waters is placed New Holland, which many geographers call a third continent; although it is perhaps more correct to consider it as by far the largest island in existence. When we find a considerable number of islands grouped together, we give the name of *archipelago* to the whole. The vast archipelago which extends to the east of the ancient continent, and in the centre of which New Holland rises majestically, seems worthy of being considered as a new division of the world, which we shall distinguish by the name of *Oceanic*.

Ancient continent.

Divisions of the world.

New continent.

The ocean. There is upon our globe, properly speaking, only one sea, one continuous fluid spread round the land, and which probably extends from one pole to the other, covering nearly three-fourths of the surface of the earth. All the gulfs, all the inland seas form only portions detached but not entirely separated from that universal sea, which we call

the *ocean*. It is only for the sake of greater convenience that we distinguish different parts of that ocean under the name of *seas*. But this arbitrary and incomplete division is at the same time the occasion of ambiguity, and varies among different nations. We adopt the following classification, the simplicity and justness of which, can be easily verified by means of an artifical globe. Classification of seas.

- A. *Great Austro-Oriental basin* or sea, occupying the greatest part of the aquatic hemisphere of the globe.
  - 1. *Austral Ocean*, or icy sea of the South.
    - Its frontier may be fixed by a line, drawn from Cape Horn to the Cape of Good Hope, from thence to Van Diemen's Land, and returning by the south of New Zealand to Cape Horn.
  - 2. *Oriental* or *Pacific Ocean*.
    - *a.* The *Great Archipelago*, or the part comprised between New Zealand on the south, the islands of Marquesas on the east, the island of Formosa on the north, and the straits of Malacca on the west.
    - *b.* *Northern Oriental Ocean*, between Asia and North America. The inland seas of Japan and Kamtchatka, and the sea of Behring, form a part of it.
    - *c.* *Southern Oriental Ocean*, from the islands of the Great Archipelago to South America.
  - 3. *Indian Ocean*.
    - With its different gulphs. The limits above mentioned mark out what remains for this section. The gulphs of Arabia, Persia, and Bengal form a part of it.
- B. The *Western basin*, forming a sort of channel between the two great continents.
  - 4. *Western Ocean*.
    - *a.* *Northern Ocean*. Its southern limit is formed by the department of France, called the Pas de Calais, by Great Britain, the isles of Faroe, and Iceland.
      The northern inland seas of Europe, and the northern icy sea, are branches of it.
    - *b.* The *Atlantic Ocean*; from the preceding frontier to the two points where the coasts of Brazil and Guinea approach nearest to each other.
      - Branches.
        1. The Mediterranean and its gulphs.
        2. The Gulph of Mexico, &c.
        3. Baffin's bay and Hudson's Bay, or the seas of the Esquimaux.
    - *c.* The *Ethiopic Ocean*, between Brazil and Africa, as far as the line from Cape Horn to the Cape of Good Hope.

In following this division upon the globe, many general results will evidently strike us.

Is it not, in the first place, very remarkable, that one half of the globe should be covered with water, while the other half contains less water than land? In order to have under our view the whole of the aquatic hemisphere, we must turn the globe so that New Zealand may form the highest point; or we must examine a map of the world, projected upon a horizon little distant from that of Paris[c]: the hemisphere, circumscribed by the horizon of our antipodes, presents to the view only some islands, some promontories, and some narrow lines of coasts in the midst of an immense sea; while the hemisphere bounded by our horizon comprises almost the whole of the land. If the masses of polar ice of the south do not contain some considerable islands, we can, by following the meridian of the Cape of Good Hope through the pole, till we reach the neighbourhood of Behring's straits, trace a line of two hundred degrees, or of four thousand marine leagues; a line exceeding by more than four hundred leagues half the circumference of the globe, and which passes over a surface entirely covered with water. A line drawn under the equator from Africa, through Sumatra and Borneo to America, passes over a surface of water, with only two or three interruptions, of four thousand two hundred leagues. Lastly, the fortieth parallel of south latitude affords an aquatic zone, interrupted only for fifteen degrees, and consequently forming a circumference of nearly five thousand three hundred marine leagues, a space little less than two-thirds of the periphery of the globe. Such is the vast extent of the Austro-oriental basin of the ocean upon our earth.

Terrestrial and aquatic hemisphere.

Dimensions of the Austro-Oriental ocean.

The form of the western basin is not less striking. It resembles a channel, narrowing towards the pole, and communicating with the Austro-oriental basin, on one side by

[c] See Le planisphère du Père Chrysologue de Gy, or the Atlas of this work.

the straits of Behring, and on the other by the large opening of the Ethiopic ocean. The Mediterranean Sea corresponds to the gulf of Mexico; the Baltic and Northern seas, are opposed to Baffin's and Hudson's Bays.

Comparison of the northern and southern hemispheres.

The distribution of water and land is also very unequal, if, without considering the forms of the two grand basins of the ocean, we compare the hemispheres, separated by the equator, or the northern and southern halves of the globe. We have found, by a pretty exact computation, that the land in each hemisphere and the zone bears to the whole surface the following proportions:

In the icy zone of the north, ...	0,400
In the temperate zone of the north	0,559
In the northern part of the torrid zone	0,297
In the northern hemisphere	0,419
In the icy zone of the south	0,000
In the temperate zone of the south	0,075
In the southern part of the torrid zone	0,312
In the southern hemisphere	0,129

Is a southern continent necessary for the equilibrium of the globe.

Geographers and naturalists, about the middle of the eighteenth century, endeavoured by various arguments to account for this unequal distribution of land and water. They asserted the existence of a great southern continent, which was necessary to counterbalance the mass of land situated in the northern hemisphere[f]. But the voyages of Cook have put an end to all these conjectures. That navigator found, up to the 70th degree of south latitude, only one vast sea, containing many floating masses of ice, together with a few islands which had been mistaken for the promontories of the southern continent. There remains therefore towards the pole only about five or six hundred

[f] Bergmann's Physical Geography. I. p. 6. (2d edit. of Upsal, in Swedish.) Dalrymple's History of Navigation, Buffon, Buache, &c. &c.

thousand square marine leagues, in which there can be any land, inaccessible to navigators on account of the ice[g]; but the whole of this mass would very little alter the proportion between the two hemispheres.

According to the opinion now generally admitted, that part of the land which is elevated above the surface of the sea, is so little in proportion to the immensity of the globe, that the effect of its unequal distribution upon the equilibrium of the globe is in fact nothing, or so small as to produce no sensible effect. Besides, it is possible[h], that the sea towards the south pole may be less deep than in the northern hemisphere, and thus the tracts of land under the sea towards the south, may counterbalance the continental masses of the north, which are more elevated indeed, but surrounded by much deeper seas. This hypothesis would be more plausible, if the greater flattening of the globe towards the south pole, indicated by the measurements of M. La Caille, in Africa[i], should ever be confirmed by corresponding measurements in America, and in New Holland; for then, that hemisphere being in general more depressed than ours, the ocean by its own tendency to establish a level, would spread itself over the surface of the southern land, which would be thus covered by the sea.

Direction of peninsulas.

The two continents present a similarity of appearance in the direction of their peninsulas; they are almost all turned towards the south. This is the case with South America, California, Alasegha, Greenland, Arcadia, Florida, Scandinavia, Italy, Greece, Arabia, India, Corea, Kamtchatka, and Africa[k]. Two remarkable peninsulas indeed,

[g] In February 1819, land was discovered by Mr. William Smith, Captain of an English brig, when his ship was in Lat. 62° 40° South, and Long. 60° West: he traced the coast for 250 miles, but it is yet to be ascertained whether this is an island of considerable size, or a part of a continent. It is by no means improbable that it may be connected with southern Thule, the most southerly part of Sandwich land seen by Captain Cook in 1775, and situated in 59. 30 S. lat. and 27° 30 W. long.

[h] Desmarets, Encycl. Method. Géo. Phys. i.

[i] See Book ii. p. 53.

[k] Bacon. Nov. Organ. L. ii. Aphor. 27.

Yucatan and Jutland stretch towards the north, but they consist only of plains and alluvial land.

But the general direction of the land is entirely different in the two continents. In the new continent it extends from pole to pole; while in the old the direction is more parallel to the equator; and if we examine only Europe and Asia, it is perfectly so. The longest straight line which we can trace upon the ancient continent, running it as much as possible over land, commences, according to Bergmann, under the 61st degree of north latitude, near the mouth of the river Ponaschka in the sea of Anadyr, and crossing over the town of Nargun, the lake of Aral, and the southern part of the Caspian Sea, passes near the Persian Gulf, and to the north of the straits of Bab-el-Mandeb; it then traverses Africa, following the course of the mountains of Lupata, or the spine of the globe, and terminates at the Cape of Good Hope. It is 148 degrees, or 2960 marine leagues in length[1]. It forms with the equator an angle of 65 degrees, and the parts of the continent, situate to the east and west of this line, are nearly equal. It is difficult to trace a similar line over the new continent. Bergmann makes it begin at the 60° north latitude, and at 265° longitude east of the island of Ferro. It continues, according to Buffon, to pass over Florida and the islands, to the mouth of the river La Plata. According to him it is one hundred and five degrees, or two thousand one hundred marine leagues in length, and makes an angle of sixty-eight degrees with the equator. According to the latest discoveries, this line ought to be prolonged ten degrees farther north; its length will then be 2300 leagues. But we cannot accurately represent the length of the new continent, except by a line containing many curves, in passing from the "icy cape" of Cook, through Mexico and Quito to Cape Horn. We shall then have a line of more than 3000 leagues in

Direction of the continents.

[1] Phys. Geog. I. 3—5. Comp. Buffon, Preuves de la Theorie de la Terre, Art. 6. The line drawn by Buffon passes above the Icy Sea.

extent. This line will divide the continent into two very unequal parts.

Proximity of the pole.

If we were to suppose that the country round Baffin's Bay, and that discovered to the north of Siberia, form an uninterrupted continuation of the continent of America, the new world must approach much nearer to the Arctic pole than the ancient world. The frozen parts would thus be much more extensive, and the torrid regions much less than those of the old continent. The solution of the difference in the climates of the two great continents seems to depend upon this fact.

Contrasted configurations.

The peculiarities of the isthmuses that divide each continent into two very unequal parts, (Suez being composed entirely of sand, while that of Panama is formed by rocks of granite and porphyry,) lead us to remark a very singular difference in those two great islands of the globe. The ancient world is in almost every part open to the advances of the ocean, and from the straits of Behring to those of Bab-el-Mandeb on the one side, and to those of Gibraltar on the other, the bays, gulfs, inland seas, &c. are, as it were, in a sort of equilibrium, at least with respect to numbers; while the mass of Africa is not penetrated by one single arm of the sea. The new continent, on the contrary, having only one considerable gulph, that of California, or the sea of Vermeille, on its western shore, presents on the opposite coast a chain of gulphs and inland seas; and when these are awanting, some immense river is found to supply the link. It is time, then, for geologists to cease from copying Buffon, when he would represent the two continents as exhibiting more breaks and inlets on the east side than on the west.

Mountains, upland plains, or plateaus.

Let us now pass from this view of the inequalities which the horizontal profile of our globe exhibits, to an examination of those which result from a perpendicular section.

Mountains form the most considerable eminences on the surface of the earth, and have their descent more or less rapid. We must distinguish them from "plateaus," or upland plains, which consist of great masses of

elevated land, commonly forming the centre of continents or of islands, but the sides of which are long and extended, and with but little apparent declivity. A plateau may have upon its elevated surface mountains, plains, and valleys. Some of them are sufficiently inclined to allow the waters which accumulate upon them to flow down; there are others which preserve the same level throughout a great extent, and where the rivers do not find any outlet. We meet with some plateaus of the latter sort in Europe, principally in Croatia and in Carniolia, but they are of small dimensions. In order to see them in perfection, we must visit Tartary, Persia, and the centre of Africa [m]. These plateaus have their general level more elevated than the rest of the continent; they seem to be the most ancient masses of land, and, as it were, the *nuclei*, or kernels, round which the additional soil accumulated.

Forms of mountains.

Mountains, in their exterior forms, present some varieties which strike even the most inattentive observer, and which, at first sight, may lead us to presume that there is some difference in their internal composition. The highest mountains most frequently present a surface of naked rock, but the nature of the rocks produces varieties in their sections and outlines: here, they shoot up into the form of enormous crystals, with sharp angles, heaped up and supported by each other; in another part, vast and elevated masses are crowned with circular summits, which rise into the air with less boldness. Sometimes there appears an immense steep and abrupt surface, which lays open to view, as it were, the entrails of the mountain itself. We describe these appearances under the names of needles, peaks, teeth, horns, domes, breaches [n]. Next in order to these broken, arid, and steep summits, we see mountains, the forms of which bear a character of tranquillity, an indication of their slow and successive formation; these moun-

Needles, Peaks, &c.

[m] See the articles *Tartary*, *Persia*, &c. vol. ii.

[n] Humboldt, Saussure, Pallas, etc. See the articles *Alps*, *Apennines*, *Pyrenees*, vol. vi. Andes, vol. iv, &c.

tains, which are still considerable, formed by strata or layers variously inclined, generally exhibit an infinite variety of forms, in consequence of the changes to which, from numberless causes, they have been subjected. In one place, a vast amphitheatre is seen rising in majestic and regular gradation, like the Kinnegulla in West Gothland[o]. In another there is a large mass cut perpendicularly, and presenting the form of an altar like the table mountain at the Cape of Good Hope. There are mountains in China, which have the appearance of the head of a dragon, a tiger, or a bear[p]. In other places, you see a labyrinth of rocks rising like pillars, as at Adersbach in Bohemia, or in one single mass in the form of a large nine-pin, as Mont Aiguille in the province of Dauphiné[q]. We see some also near Envionne in the Valais, which recal the figure of the old French frizzled wigs, (*perruques moutonnés.*) But the most common appearances are those formed by layers of stones, in an undulated or furrowed shape.

After these mountains of the second rank, we find hills more or less lofty, which, on all sides, present to the eye but little elevation, and a gentle declivity. These hills, furrowed by streams of running water, often gradually slope away, and at last lose themselves in the plains. Sometimes their sides are so rugged and precipitous as to produce on the mind almost all the picturesque effect of high mountains.

Volcanic peaks.

The peaks, or higher parts of mountains, formed by volcanic agency, differ very much from the usual forms. Their conical or pyramidal masses are distinguished by their regularity even when they have been broken off, or truncated, by some accidental cause. Their towering summits seem to menace the neighbouring country. The basaltic mountains also present an appearance not less striking, when they are not covered and concealed by other soil. Their sides dis-

[o] Mem. de l'Acad. de Stockholm, 1717, pl. iii.

[p] Osbeck's Voyage to China, 266. in Swedish.

[q] Lancelot, les Merveilles du Dauphine, dans les Mem de l'Acad. des Inscriptions, tom. ix. Saussure, Voyage dans les Alpes, sec. 1061.

play to the view close ranges of immense pillars or causeways, which seem to be the production of giants. The description, however, of all the forms which these rocks exhibit, would lead us away from the subject of this book.

Perforated mountains.

There is, however, one eccentricity of nature, if it may be so called, which deserves to be noticed here, namely mountains bored through. Some have supposed that such perforations have been accomplished, in part at least, by the persevering industry of man. The Pierre-Pertuise in Mount Jura, and Pausilippo near Naples, are instances of this kind. But nature has left unequivocal marks of her power in other phenomena of this kind. The Torghat in Norway is pierced by an opening one hundred and fifty feet high, and three thousand long. At certain seasons of the year the sun can be seen darting its rays from one extremity to the other of this vault[r]. Near New Zealand there is a rocky arch through which the waves of the sea pass at high water. These phenomena differ from caverns, only from the circumstance of having a passage entirely through.

Chains of mountains, and insulated ones.

Another general point of view, in which mountains may be considered, is their position relatively to each other. Some are completely insulated, more particularly those of a volcanic origin; it is the same also with those of a calcareous nature and some others. Both China and Iceland furnish many examples[s]. The rock of Gibraltar and the fortress of Gwalior in Hindostan are of this description. We may also mention Mount Aornos, where a whole people supported a siege against Alexander[t]. Mountains are seen most frequently in groups. Sometimes chains branch out from a common centre in angular directions. Sometimes the centre mass itself is a lofty chain, straight or curved, whence, at different periods, secondary chains have apparently been formed;—the Alps may be placed in this class. Sometimes we see irregular groups of several chains, among which no one in particular can be ranked as the principal.

[r] Pontoppidan's Natural History of Norway, i. 75—79, (in Danish.)
[s] Bergmann, Geog. Physique, i. 171. [t] Quint.-Curt.

Such are the collections of mountains in Asia Minor and in Persia. But the most remarkable sort is that of long connected chains, which, like the Cordilleras des Andes in South America, continue for hundreds and even thousands of leagues, nearly in one constant direction, having on both sides regular layers or ranges of inferior mountains, but sending off very few secondary chains. These great chains evidently bear the stamp of the highest antiquity, and seem to have been the silent witnesses of the creation; it is upon their summits and their sides that we can read the history of the globe in characters more distinctly defined, than even those which the Alps and the Pyrennees afford.

Connection of chains.

In general all the chains of mountains in the same continent, seem to have a mutual connection more or less apparent: they form a sort of frame work to the land, and appear, in the origin of things, to have determined the shape which it was to assume; but this analogy, were we to generalise too much, would lead us into error. There are many chains, which have very little, or rather no affinity to each other. Such are the mountains of Scandinavia and of Scotland; mountains as independent as the character of the nations who inhabit them.

In making use even of the word "chain," great caution is required. A chain may be defined to be a series of mountains, whose bases are continuous; but then we must not push the meaning of the word "base" too far. It would perhaps be of advantage to understand by this term only the visible foot of the mountain, or at most the interior strata, which can be easily traced near the surface. At any rate, we must beware of considering collections of hills, or banks of sand, as continuations of chains.

We must, however, acknowledge, that the name of chains is not sufficiently general, and that it would be better to reserve this word for the subdivisions, and to employ the "term system of mountains," or "mass of mountains," to denote a collection or combination of many chains.

Declivities of mountains.

Mountains, whether insulated or in groups, exhibit on both sides declivities which are either gentle and long, or rapid

and broken. We ought particularly to remark this general fact, that the greater number of the principal mountains have one of their sides very steep, and the other of a very gradual slope[u]. The Alps, for example, are much more rapid in their descent on the Italian side than on that of Switzerland. On the contrary, the Dophrines, or Scandinavian Alps, have a much steeper declivity to the west and north-west, than towards the south and east. The Pyrennees are steeper towards the south than the north; the mountains of the Asturias are the reverse; but those of the Sierra-Morena, and particularly the Alpujarras in Grenada, seem to be steepest and most abrupt towards the south. Mount Atlas and Mount Libanus border the Mediterranean with bold and craggy declivities. But, with regard to the latter at least, it is certain that towards the Euphrates it is far from steep. Mount Taurus (supposing it to terminate at the source of the Euphrates) exhibits two very different declivities; for in Caramania and Natolia, the descent is very abrupt towards the south, while there are some very extended upland plains, or plateaus, towards the north: in Armenia, on the contrary, the declivity on the north side is very rapid. The Ghauts, in the peninsula on this side the Ganges, have precipitous hills directly towards the west, and long and rather gentle slopes towards the east. Thus there is no constant rule; every thing depends upon local circumstances. In general this inequality in the declivities takes place only because the chains of mountains, when most distinct, are in a great measure nothing but the abrupt borders of long upland plains, or plateaus obliquely inclined, of which the surface of the globe seems to be composed. We ought also to distinguish the mountains, which descend by degrees, or successive banks, a circumstance attributed sometimes to the sinking of parts of the soil, which had been of a different nature from the rest, and sometimes to the action of the water which formerly may have flowed at the base of these mountains.

[u] Delamétherie, Theorie de la Terre, etc.

Valleys are formed by the separation of chains of mountains or of hills. Those which are found between high mountains are commonly narrow and long, as if they had originally been only fissures dividing their respective chains, or for the passage of extensive torrents. The angles of their direction sometimes exhibit a singular symmetry. "We see in the Pyrenees," says[x] M. Raymond, "some valleys, whose salient and re-entrant angles so perfectly correspond, that if the force which separated them were to act in a contrary direction, and bring their sides together again, they would unite so exactly, that even the fissure would not be perceived." This fact has been observed in the Alps for the first time by Bourguet, who has generalised it too much[y]; for there are some valleys, situated on a high level, totally different. We see some which have a great extent in length without being cut into any angles whatever, forming a sort of elevated plains; such are generally those which lie on the side of the principal chains, the Valais, for example. There are others which are large or swelling; Bohemia or Cachemire are instances of this sort. It is asserted, that they have been the basins of some ancient lake, which had become dry from the breaking down of the bank or dam formed by the surrounding mountains. This hypothesis, developed by Lamanon and Sulzer[z], appears to be one of the best founded of any which geologists have proposed. There are also some highly situated valleys, containing rivers and lakes which have not outlets or streams. There is a remarkable example of this in Peru, in the large valley which contains the lake of Titicaca. Central Asia abounds in such valleys. Several nearly of the same sort are to be met with in other countries; and many more will one day be discovered in the interior of Africa.

Valleys in the form of basins.

[x] Observations sur les Pyrénées.

[y] Memoire sur la Theorie de la Terre, à la suite des Lettres Philosophique sur les Sels et Cristaux, p. 181. Comp. Buffon, Hist. Nat. edit. 12mo. i. p. 105.

[z] Sulzer, Encyclop. Method. Phys. Geogr. i. art. Delamétherie, § 1514, &c.

High valleys present also some remarkable circumstances as to their form. Some have declivities equal on all sides; others slope only on one side, and to a great extent, while the opposite side is steep and abrupt. Most of these high valleys have their surface upon a level with the summits of the secondary mountains in the neighbourhood. The level of the lake of Joux, in a valley of Mount Jura, is considerably higher than that of the lake of Geneva[a]. In a few instances these high valleys have been observed to enlarge themselves at different and successive periods, and gradually to become identified with the plains. They have been for ages almost completely barred and confined by some projecting angle of the chain of mountains, which girds them in. The sort of narrow passage, by which we enter into these valleys, is called a pass or defile, and as formerly each valley contained a small independent nation or tribe, these passes are called by the French, "les portes des nations." Such were the passes of Caucasus, the Caspian passes, the pass of Issus, rendered celebrated by the victory of Alexander; that of Thermopylæ, immortalized by the devoted patriotism of Leonidas and his band of Spartans. The Caudinæ Furculæ, where Rome saw the glory of her unjust arms deservedly tarnished. There is between Norway and Sweden one of these passes, formed by several masses of rock, cut by nature into the shape of long parallelograms, and which have between them a passage, shut in by perpendicular walls. This pass is near Skiærdal. Another of the same kind is at "Portfeld," or the mountain of the gate[b]. These openings exactly resemble those by which the Hudson River in North America passes through successive chains of mountains, which seem desirous of checking its course[c]. The Cordilleras of the Andes present the most stupendous passes of

Inclination and level of valleys.

Passes, defiles, &c.

[a] Saussure, Voyages, p. 376, *sqq.*

[b] Bergmann, Geog. Physique, i. 185. Cronstedt. Description de la Iemptie, dans les Mem. de l'Acad. de Stockholm, 1763, p. 275.

[c] Kalm's Travels in America, iii. 161. (in Swedish.)

this kind, that are known; they are from four to five thousand feet deep[d]. The lower valleys appear to us under a very different aspect; they widen as they recede from the secondary mountains from which they originate, and gradually lose themselves in the plains. Their opposite angles generally correspond very regularly, but these angles are very obtuse.

Low valleys.

High and low plains.

Plains, like valleys, are of two classes: the high plains, which are found between two chains of mountains, are frequently of great extent, and are placed as it were upon the shoulders of the secondary mountains: such are the elevated plains of Tartary, of Persia, and probably of the interior of Africa. The plains of Quito are 12,000 feet above the level of the sea: those of Karakorum, in Chinese Mongolia, are probably as elevated. The low plains, whose soil is composed of sand, gravel, and shells, seem formerly to have been the basins of interior seas. Such are the plains on the north side of the Caspian, the large plain to the south of the Baltic, and that through which the river of the Amazons flows; the Tehama of Arabia, the Delta of Egypt and others of a similar nature; which seem to have been once covered by the waters of the ocean and its gulphs.

The coasts or shores of the sea, and of lakes, deserve also great attention. These are the extreme limits of our system of mountains. Some shores are broken and steep; this happens, when a mass of rock extends, either beneath or above the surface of the soil quite to the water; as in Gallicia, in Bretagne, in Norway, and in Scotland. This description of coasts admits of two subdivisions. 1st, We have those which are abrupt and broken, and as it were notched, formed by various masses of rocks united at their bases, either above or beneath the surface of the water: these rocks often form clusters of islands, which surround the coasts; such are the "garden of the king," and of the "queen," at Cuba, the archipelago of Mergui in India, the

Coasts steep and indented, &c.

[d] Humboldt, Vues des Cordilleras, p. 9.

coasts of New South Wales, the Skiergôrd of Norway and Sweden. This class may again be subdivided according as the steepness of the shore, arises from true granitic and other rocks, or from those masses of coral formed by the polypi which fill the seas between the two tropics. 2dly, We have coasts where the shore or boundary is equally steep above and below the surface of the water, leaving the sea itself quite free; these are, strictly speaking, the "steep coasts." Such, in general, are those of the Mediterranean and of the Black Sea: those of Dalmatia and some parts of the Archipelago more properly belong to the first division. America possesses scarcely any other variety of coasts on the side of the Pacific Ocean, beginning at Cape Horn and proceeding to Behring's Straits. This is the largest continuation of steep shores known upon the globe. Mariners call a coast bold bluff, when it meets the ocean with a rapid declivity, and clear, when it is not bristled with rocks.

Low coasts are formed by land of a softer quality, approaching the water by a gentle and gradual slope. These may be thus classed; 1. Coasts formed by hills. Such are those of all the Danish islands, of Scania and Pomerania, consisting chiefly of calcareous matter. Shores of this kind seem more particularly to belong to lakes and small inland seas, although indeed the basins containing these are often surrounded by steep shores, as grand and bold as those which border the ocean. 2. Flat coasts, formed by sands and substances which the sea has deposited. These appear under the form of sandy or marshy plains, and extend a long way into the sea, leaving the water more or less shallow. They are, however, of various kinds. They are sometimes like those in Gascogne and Jutland, the ancient sides of low hills, round which the sea has collected masses of sand, which are either fixed or shifting: sometimes they are a sort of downs*, formed by the sea,

Coasts formed by hills.

Coasts formed by downs or flats.

* The low and flat ground at Yarmouth, in Norfolk, between the sea and the river, is called the Danes or Daines, evidently from the French word "Dunes." T.

together with soil deposited by large rivers, as in Holland, in Egypt, and at the mouth of the Mississipi. A collection of slimy matter is also sometimes formed by the ocean, as in the flat and flooded lands on the shores of French Guiana. The low coasts are sometimes exposed without any natural rampart, to all the fury of the waves, and then we may, with Tacitus, be uncertain whether to regard them as constituting a part of the land or a part of the sea; others are secured by a chain of downs that are fixed and mingled with rocks like North Jutland. It was only by a skilful and persevering imitation of these natural barriers, that the Dutch recovered the soil of their country from the empire of the ocean.

Islands. Islands of great extent exhibit on a small scale the same appearances as the continents do on a large one. The smaller islands, however, deserve a distinct consideration. These may be classed in various ways. They are single, or in groups or chains. Among the low or flat Flat. islands, there are some which are only banks of sand, scarcely raised above the surface of the water; sometimes they consist of masses of shells or petrifactions, as the isles of Lachof to the north of Siberia, which are nothing but masses of ice, sand, and the bones of the mammoth. The greater number of the islands of the South Sea, formed, or at least enlarged by polypi, are composed solely of coral or Volcanic. madrepores. Among the more elevated islands, we find very many, which owe their foundation, in a great measure at least, to the action of volcanoes, which, after bursting forth from the original summit of the island, have continued to discharge lava from their crater in all directions, until by slow and gradual accumulation they have formed those vast and lofty peaks, which serve as land marks to the distant Chains and groups of islands. mariner. When groups of islands are placed near each other, we may fairly conjecture that they are only the different summits of one extensive submarine mass. So also, when they appear to follow one constant direction, they probably form only the eminences of a chain of submarine mountains. Such, when situated in the same line with the

promontory of a continent, or with mountains on shore, may be considered as a continuation of the chain. Thus, it is evident, the Kurile islands connect Yeso or Jesso with Kamtchatka, in the same way as the great and small Antilles connect the two continents of America. But to make the observation hold, the intervals which separate the islands must either be very small, or be filled up with rocks and shoals beneath the surface, so as to preserve unbroken the continuity of the bases of these maritime mountains. Thus, the supposed connection between the Canary Islands, the Azores, and mount Atlas in Africa, though possible, requires to be verified by repeated soundings, so as to discover the nature of the bottom of the intervening sea.

Mountains, in general, have no precise and regular direction. The chains, sooner or later, bend and deviate into a curve, and frequently lose themselves in plateaus, or upland plains.

Chains of mountains, and divisions of waters.

We must not therefore give the reins to our imagination, and pretend to trace entire series of terrestrial and submarine chains, and thus form a frame-work for the globe, which has no existence in nature[f]. It is not sufficient to see upon a map, that there is in a particular place a division in the seas. There are many such divisions in the world, which afford no traces whatever of mountains, but only of extended plateaus, or upland plains, which rise with a gentle inclination on both sides, often for the space of a hundred leagues. We meet with no lofty mountains, but a collection of hills, in the centre of European Russia, although this is the centre whence some of the largest rivers of Europe diverge. Nay, there is actually in Russian Poland, between the Niemen and the Duina on one side, and the Dnieper and Dniester on the other, a point of division, which affords no sensible elevation whatever, and where, instead of the mountains laid down by

[f] Ph. Buache, Essai de Geographie physique, dans les Mem. de l'Acad. des Sciences, 1752, p. 399.—Comp. Lehmann, Specimen chorographiæ generalis, tractus montium primarios sistens. Petrop. 1762.

Buache, travellers have discovered only a marshy plain. Even about the middle of the course of the Dnieper, there is a mountainous elevation, consisting of pebbles and shells, which that river passes through, following a deep fissure or glen, in which it runs[e]. On the other hand, the Niemen passes round some hills of Eastern Prussia, much more elevated than the point of division of the waters, as is shewn in Fig. 48, which is the profile of Europe, between the Baltic and the Black Sea. A total difference may be observed between this profile, and that which the same quarter of the world presents, bisected in the direction of the gulphs of Genoa and Hambourg, (Fig. 49.) and both these again form a contrast with that of the plateau of Mexico, (Fig. 50.) and of South America. (Fig. 51.) one of which is copied from the original, in the possession of M. Humboldt, and the other from a scale of heights, published in his travels. We may easily judge into what absurdities we may be led, should we have recourse to any general system whatever, for the purpose of discovering facts, of which observation alone can point out to us the astonishing variety.

Submarine chains.

The system of Buache has given rise to those chains of submarine mountains, which do not in fact exist, but which, nevertheless, make a figure in some theories of the earth. A detached island, a sand-bank, a reef of rocks at the surface of the water, are sufficient, in this author's opinion, to indicate a submarine chain, between two points of the world, however distant from each other. Nay, sometimes he has not deigned to assign any reason whatever for his conjectures. For example, he would represent Iceland, the Faroe Isles, and those of Shetland, as forming one submarine mountain between Greenland and Norway, notwithstanding that there is a deep sea between Norway and Shetland; and that from the direction of the mountains being parallel, and not converging, these chains could in fact

[e] Hydrographical chart of Poland by Rountan and Komarzewski. Map of Rizzi-Zannoni. Notes by MM. Stibielowitz and Niemcewski of Wilna.

never coincide. Besides, the basaltic nature of Scotland, of Ireland, of Faroe, and of Iceland, seem to point out an ancient union of the British Islands with Greenland, rather than with Norway. In the same way, the submarine chains of the South Sea, have in general a direction quite different from that which Buache ascribes to them, according to the uncertain discoveries of his time. They have not the least connection either with Mexico or South America, any more than with the imaginary Austral continent. Many of these chains of islands, and particularly those which are the most insulated, have a very remarkable direction, but entirely opposed to the system of Buache; they extend from north-west to south-east, in the direction of the magnetic axis of the earth.

General direction of the mountains of the earth.

Let us however examine, notwithstanding the erroneous hypotheses of our predecessors, whether we cannot introduce general views more conformable to the truth, in our attempts to trace some sort of constant analogy, in the direction of the mountains of the two continents.

If we draw a line from the centre of Thibet, across Chinese Mongolia, towards Okotsk, and thence towards Cape Tchutchi, or the eastern promontory of Asia, this line will in general coincide with an immense chain of mountains, which run from the south-west to the north-east, and every where descend very rapidly towards the Indian and Pacific Oceans; while on the other hand, they extend themselves towards the Icy Sea, in plains and secondary hills. It is probable that we may one day be able to reduce to the same rule, the chain of Lupata, called the "Spine of the world," which is situated in Africa; at least, the short chain from the Cape of Good Hope to that of Guardafui, in a direction of south-south-west, and of north-north-east, which is nearly the same direction as the great chain of Asia; but we are still ignorant of the declivities of these mountains. We may consider the lofty and steep mountains of Arabia Felix[h] as the link which connects the

[h] Seetzen, dans Zach. Astron. Corresp. xi. See "Arabia," vol. ii in this work.

mountains of Lupata with the plateaus and mountains of Persia, on the side of Thibet.

From Behring's Straits to Cape Horn, if we follow the western coasts of America, we shall find one unbroken chain of the highest mountains of our globe. This chain occasionally bends a little into the interior, but it more frequently closely borders the ocean, with a range of steep and bold shores, and sometimes with the most tremendous precipices. On the other side, the outlets of lakes, and the direction of the great rivers, evidently shew that nearly the whole surface of America inclines towards the Atlantic Ocean.

Great chains of the globe.

It follows from these combined observations, that the greatest chains of mountains upon the face of our globe are ranged in a circle round the Great Ocean, and the Indian Sea; that they more frequently exhibit steep and rapid descents towards that immense basin, which they surround, and long and comparatively gentle declivities on the opposite coasts; that in short, from the Cape of Good Hope to Behring's Straits, and from thence to Cape Horn, the eye even of the most severe and scrupulous observer, cannot fail to discover some links of an arrangement, as astonishing from its uniformity as from the immense extent of country which it embraces.

Let us stop here for a moment, and consider this great fact of physical geography. If we suppose ourselves placed in New South Wales, with our face turned towards the north, we shall see America on our right, Africa and Asia on our left. These continents, which, not long since, we could not even in imagination, consider as at all approaching each other, being examined from this point of view, form, as it were, one whole, the structure of which, as far as it is known, exhibits in its grand features a most amazing symmetry. A chain of enormous mountains surrounds a vast basin: this basin, divided into two by a large mass of islands, frequently washes with its waves the base of this great primitive chain of the earth. But when did this immense chain of granite and porphyry shoot up from the bosom

of the waters? Or when did those lofty secondary mountains sink into the depths of the ocean, and by their simultaneous submersion, form that steep and abrupt range of coast, which predominates over this globe? Shall we suppose that the earth was formerly, like the planet Saturn, surrounded by a ring, and that this celestial vault, losing its equilibrium[1], was precipitated upon the surface of the earth? But to what length will imagination wander, emboldened by seductive, but vague and inconclusive analogies? Let us then return to the old continent, and recollect, that the vast regions of India and China, contrary to such analogies, are placed to the south of this great girdle of mountains; that the peninsula beyond the Ganges even joins that astonishing group of broken and intersected countries, which fill the centre of the great basin; and that this is as it were the link which connects with the present continent, those grand remains of a former continent, of a hemisphere, which seems to have disappeared.

General inclination of continents.

If again we consider under the same point of view the whole extent of the two continents, which, in regard to the great ocean, is placed beyond this principal chain of the globe, we shall perceive that the greater part of the plateaus, or upland levels, and of the chains of mountains, incline very generally towards the Atlantic and Northern Oceans. That extent of waters, vast as it is, appears then only like a canal, if we compare it with the great Pacific Ocean. The steep coasts which border the Atlantic, are nothing in comparison with those of the Cape of Good Hope and of Cape Gardafui, with the precipices which surround the seas of Kamtchatka, of Peru, and of Chili.

Elevation of mountains.

We may expect, perhaps, to find likewise a certain general analogy among mountains, in regard to their height; but we must at once confess, that we are still less acquainted with the real height than with the direction of the principal chains of mountains. Our mea-

[1] Comp. Laplace, Syst. du Monde, l. iv ch. 9. p. 255, 3d edit.

surements, whether taken trigonometrically, or from the comparative height of the barometer, have been made to no great extent, except in Europe and America. But in such general observations upon the whole of the globe, Europe cannot be regarded as a very important part, or as a standard of comparison much to be depended upon; because the summits of our Alps, such as Mount Blanc, Mount Rosa, the Ortelos, are elevated only about 14 or 15,000 feet, while those of the Cordilleras, Chimborazzo, Antisana, and Pichincha, tower to the height of 19 or 20,000, is that a reason to conclude, that the new world has in general loftier mountains than the old, or that the mountains increase in elevation as they approach the equator? One of these conclusions is, and will continue to be hazarded, until the intrepid Humboldt has measured the Alps of Thibet, more elevated still, perhaps, than Chimborazzo; the other is decidely false, since the Andes of Chili are reckoned to be as high as those of Peru [m]; the volcanos of Mexico are but very little inferior to those of Quito; and the enormous peaks of Spitzbergen and Greenland, appear to equal the Alps, and very much to surpass the mountains of Norway and Russia, to which, according to the hypothesis, they ought to be inferior. It is proper, therefore, to reserve, until we enter upon the description of the several parts of the world, the few general comparative observations suggested by those mountains whose heights have been already determined.

[m] Molina, Hist. Nat. de Chili.

BOOK VIII.

Continuation of the Theory of Geography. Of the Interior Structure of the Solid Parts of the Earth. Of Banks or Shelves, Strata, Caverns, and Veins.

LEAVING the surface of the earth, which itself is so imperfectly known to us, and descending into its interior, our knowledge of which is still more confined, we are now about to consider the solid crust of the globe, in so far as it has been examined in reference to its interior structure, and the substances of which it is composed.

Strata, beds, &c.

To whatever depth excavations have been made in different countries, they have uniformly shewn that the greater portion of the earth consists of strata of materials of different natures, irregularly disposed. When these strata are of a similar nature, and of great thickness, they are called beds or banks (*bancs.*) If they preserve a horizontal position, we call their subdivisions layers (*assizes.*) But, although we find, even upon the highest mountains, banks, if not layers, the almost vertical position of the principal masses of most of the higher mountains, obliges us to give them the name of blocks (*blocs,*) although this name by no means points out the nature of these masses, which some regard, with much probability, as enormous crystals [a], while others affect to consider them only strata changed in their position [b]. Sometimes the blocks, or beds, are divided by

[a] Delamétherie, Théorie de la Terre, sec. 1339, *et seq.* Patrin, Hist. Nat. des Mineraux, i. 103.

[b] Saussure, Voyage dans les Alpes, sec. 604—669. Compare his opinions, sec. 1691 and 2300. Deluc, Lett. Géolog. à Blumenbach, p. 123. (En Fran.)

We have adopted the terms of our author, though they by no means coincide with those used by our own writers upon geology and mineralogy; but, in order to prevent mistake, we have in general given the French term also.—*Translator.*

vertical fissures, and then their portions may be called leaves, or laminæ, *(feuillets* ou *lames.)* We regret that these terms convey no precise and fixed meaning; but we also acknowledge, that, in contemplating the objects of nature, it is impossible to submit them to a more rigorous classification [c].

The different masses which we are about to describe, are thrown one upon the other in every possible manner, both horizontally and at every angle. Frequently in moderate elevations, and more particularly in low lands, the different strata preserve, for hundreds of leagues, a parallel position; thus the limestone or calcareous strata containing numerous shells, upon which the city of Paris is built, extend across what was formerly called the Isle of France, as far as Belgium [d]. The gypseous strata of Montmartre, and of the heights of Belleville, have the same degree of elevation, though separated by a valley. In Champagne, a large bed of chalk runs nearly upon the same level from Rhetel to Sens [e]. Even the most perfectly crystallized rocks appear sometimes to follow a horizontal direction. A ridge of granite seems to extend straight from the Limosin, by Poitou, to Cherbourg in Normandy [f]. Another girdle or band of granite follows the valley of the Upper Loire from Creuzot and Mount Cenis to Saint Etienne through a space of seventy leagues [g]. Rocks of trapp similar to those in Westrogothia are found again upon the same level in some mountains separated by extensive plains. In the island of Rugen in Pomerania, in the Danish island of Mœn, and at Stevens in Zealand, the strata of chalk and flint correspond with each other, though an open sea flows between their bases. What confusion, nevertheless, do we

[c] Bergmann, Géog. Phys. i. 197.

[d] Cuvier et Brongiart, Annales du Muséum, vi.

[e] Linck, Voyage en Portugal, i. 48. Dupin, Statist. des Deux-Sèvres, 105. Journal des Mines, No. viii. p. 27—29.

[f] Delamétherie, Théorie de la Terre, iv. sec. 951, sec. 1151.

[g] Brulé, Statist. de l'Aube, p. 6.

find by the side of this tranquil regularity of formation! What traces of destruction at once alarm and delight the observer of nature!

In the plains, and on moderately high mountains, we meet with strata that have been entirely inverted, or partly shifted from their first position, bent in every shape, crooked and curved, and returning upon themselves; the mountain of Saint Gilles near Liege exhibits all these anomalous appearances [h]. Strata inverted and shifted.

We find considerable strata in Mount Jura, which, having been overturned or pushed forward upon others, have stopped in a position so precarious, that the application of the least force would put them again in motion [i]. The Alps exhibit a striking spectacle of disorder and confusion. We discover pyramidal mountains, like the needle of the south, the layers of which are ranged round the axis of the pyramid like the leaves of an artichoke, if we may be permitted to compare those enormous rocks to a small vegetable [k]. Nant d'Arpenaz presents to our view a sort of hemisphere, composed of regularly curved strata [l]. At every step, the rules which appear most generally followed, are broken and set at defiance by the greatest possible diversity. If Mount Blanc be composed of enormous vertical blocks, Mount Rosa, equally gigantic, presents only horizontal strata, a little inclined. Strata concentric and curved.

These strata are almost all intersected by fissures and cavities more or less considerable. Some consist of interstices left between two ancient rocks at the moment of their crystallization; the great majority appear to owe their origin either to the retiring or sinking of the earth. The first of these causes has considerably increased them in the calcareous mountains of secondary formation; they are less frequent in gypsum. Some of these fissures have been filled with metallic substances, some by the filtering of wa- Cavities and fissures of the globe.

[h] Delamétherie, l. c. sec. 1382, 1383, pl. vi. &c.

[i] Bertrand, Nouv. Princ. de Géologie, p. 182

[k] Saussure, Voyage, sec. 569.

[l] Ibid. sec. 473.

ter impregnated with stony matter, others by incrustations, by alluvial minerals, by vegetable and animal earths; lastly, some have remained open, and form ravines, precipices, abysses, when they are open to the sky; or caverns and grottos, when they have walls and a natural roof.

In another part of this work, we shall point out and occasionally describe at length the most remarkable caverns and grottos of our globe; but we must here confine ourselves to general views. There are some very considerable caverns; frequently the first excavation is only the vestibule to another much deeper and larger, but the dimensions of caverns have generally been much exaggerated. The depth of that of Eldon Hole, near Castleton in Derbyshire, has not been discovered, though sounded with a line of more than 9600 feet [m]. Near Frederickshal in Norway, there is a hole, into which, if stones be thrown, two minutes appear to elapse before they reach the bottom, from which it has been concluded that the depth was upwards of 11,000 feet [n]. Among the numerous caverns of Carniola, that of Adelsberg is said to afford a subterranean walk of two leagues; but this computation of rather too enthusiastic a writer requires to be confirmed [o]. Many caverns are remarkable for various natural curiosities. There are some from which, in summer-time, an ice-cold wind issues with astonishing force. Mount Eoto near Turin in Italy is an example of this [p]. There are others, the walls of which are in autumn covered with ice, which melts in December. There are two or three in France that have attracted notice; among others the grotto of Notre Dame de Balme near Grenoble [q]. The little communication which these caverns have with the external air, causes them to change their temperature

[m] Lloyd, Phil. Trans. 1771, vol. lxi. part i. No. 31.

[n] Pontoppidan's Natural History of Norway, i. 101.

[o] Valvasor, Gloire de la Carniole, 1699.

[p] Kircher, Mund. Subterran. lib. iv. 239. (Compare the Grotto of Motiers in Bernoulli's Description of Neuchâtel p. 32.)

[q] Mem. de l'Acad. des Sciences, 1755, p. 149, &c.

long after it becomes changed upon the surface of the earth. The most interesting caverns, and the most curious for their natural productions, are certainly those from whose roofs water, impregnated with calcareous matter, has dropped, and which, either becoming hardened by degrees, remains suspended from the vaults of the caverns, in the shape of long crystals, or falling to the ground, assume a thousand fantastic forms, often representing various vegetables and animals. It is to this circumstance that the grotto of Antiparos owes its celebrity. The naturalist prefers those caverns which contain petrified bones. These are the visible remains of some vast burial places, where the revolutions of the globe have deposited whole generations of living beings. We are also acquainted with some caverns, whither certain species of marine animals have retired, when they felt themselves about to expire.

Stalactites.

Bones.

There are caverns which contain deep pits of water, or wells, sometimes so extensive as to acquire the name of subterraneous lakes. There are others from which rivers derive their source: while some are known to receive very considerable streams, which lose themselves in the interior. Such are the innumerable cavities of the Julian Alps, in Carniola and Croatia. It is to similar reservoirs that we must attribute the periodical disappearance of the lake of Cirknitz[r]. There are some caverns in Norway, where, as you walk upon an arched calcareous floor, you hear the roar of invisible torrents under your feet. Many caverns in Russia and in Siberia, have been evidently formed by means of water, and even masses of ice[s].

Wells in caverns.

Volcanic caverns form a distinct class. That of Surtur in Iceland, which is 5034 feet long, has three of its sides, or walls, covered with a greenish black varnish, formed by a volcanic vitrification. Long pieces of lava are suspended from the roof, which is so chinky in many places, as to admit the rays of the sun[t]. The most

Volcanic caverns.

[r] Hacquet, Voyages dans les Alpes Juliennes.

[s] Pallas, Voyages, i. 41, 56, 166. (en All.) Lepechin, Gmelin, &c.

[t] Olafsen, Voyage to Iceland, i. 127. in German.

magnificent of all the known caverns, is doubtless that called "Fingal's Cave," in the isle of Staffa, on the western coast of Scotland. Thousands of majestic columns of basalt support a lofty roof, under which the sea rolls its waves, while the vastness of the entrance allows the light of day to penetrate the various recesses of the cave [u]. The origin of these caverns with basaltic columns, is as uncertain as that of basalt itself, which has occasioned so many discussions among geologists.

The causes which have produced those cavities have unquestionably had a sphere of activity to which our observations are far from being commensurate. Many phenomena, particularly earthquakes, seem to indicate the existence of much more considerable cavities than those which are known to us. But the wisest course we can pursue, is to acknowledge our perfect unacquaintance with their nature. We no longer live in an age when Athanasius Kircher dared to describe the subterraneous world, as if he had travelled through it in every direction. The *unknown* is now banished from the land of science, and is become the exclusive patrimony of romance-makers.

The small fissures which pass through the masses of rocks, and which we call by the general name of veins, although they present to the imagination a less striking appearance than that of caverns, yet to the eye of reason and of science, exhibit a still more complicated enigma. The essential character of a vein, is that of cutting or passing through a mass of rock, in a direction more or less different from that of the strata or layers, of which the rock or mountain is formed, and being filled with a mineral substance different from that of which the rock itself is composed [x]. We sometimes find veins of twenty or thirty feet in thickness, while others are less than an inch. Some continue for the space of several leagues, others divide and

[u] Faujas de Saint Fond, Essai de Géologie. ii. planche.

[x] Werner's Theory of Veins, in German, translated into French by Daubuisson, § 2. Oppel, Géometrie Souterraine. Ibid. § 15. § 19.

disperse themselves in smaller veins. There are cases in which the veins, after having passed through many strata, suddenly break off at the commencement of a stratum of a particular sort, and re-appear on the opposite side, exactly in the same direction, and of the same thickness that they had at first [y]. The general line of veins is rectilinear, but without any preference as to direction. In the middle class of mountains, they follow the direction of the valleys. The matter with which the vein is filled, frequently contains metallic ores, and is then called *Gangue*, or that part to which the metal adheres. There is scarcely any mineral that is not found in some vein or other, more or less abundantly. Some also contain petrifactions, which seems to prove, that these fissures were originally empty, and had been filled from above, by means of a fluid loaded with various substances, which it deposited in them. This is the opinion of the celebrated Werner, and what is most generally admitted; it is however disputed by those, who consider minerals as produced by means of subterranean exhalations [z], or from some fermentation in the masses of rock, capable of transmuting the nature of its substance [a], or lastly, from the general crystallization of the globe [b]. Some philosophers have regarded metallic veins as branches of a grand metallic trunk, concealed in the interior of the globe, and to which they have attributed a sort of vegetation, or organical motion [c]. The theory of veins, however, according to every supposition, is very difficult to comprehend. We will now return to the consideration of mountains in general.

Direction of veins.

Formation.

The thickness of the various strata, differs as much as their inclination or position, and as their fissures. The bank or bed of trapp in Westrogothia, is in many places a hundred feet thick, and in the Alps there are some masses

Thickness of strata.

[y] Ferber, Oryctography of Derbyshire, 19, 20. Werner, § 73.
[z] Henckel, Pyritology, ch. 13.
[a] Trebra, Observations sur l'Interior des Montagnes, (en All.)
[b] Delamétherie, Théorie de la Terre, § 1353.
[c] Lehmann, Traité des Matrices des Métaux, Berlin, 1753.

still thicker: but it is not agreed whether these masses are to be considered as regular strata. Many of the middle class of mountains contain beds of mineral or rock-salt, of alum, and of coal, thirty or forty feet thick. But there are also some strata of coal near Liege, which are not more than an inch in thickness. White and black marbles are found in thicker strata than those which are variegated; and in general those substances which are least mixed or compound, are found in the greatest masses [d]. In Europe, continued strata or beds, of the thickness of three thousand feet, are extremely rare, but in Mexico or Peru, there are masses of porphyry, which are from 9000 to 12000 feet thick [e]. This massive structure, seems to be the peculiar character of regions, which form what we call the great chain of the globe [f].

Order of supra-position.

It remains for us only to consider the various strata of the earth, in regard to the order of their supra-position, but although this is intimately connected with the subject at present before us, the structure of mountains, it is very difficult, if not impossible, to treat the matter so as to be distinctly understood, without anticipating the observations to be made, when we come to examine the origin and nature of the substances, of which the strata are composed.

Primary and secondary strata.

We call those beds or strata *primary*, which are found at the greatest depths to which man has been able to penetrate. These masses do not in general contain any traces of animals or vegetables; and in this point of view they may be called *primitive*, or *primordial*. The next order, or that of *secondary* strata, comprehends all those masses which form mountains, and which are placed in regular strata or layers, containing the remains of animals and vegetables, and lying or resting upon the primary strata. The third order consists of such beds as contain fragments of secondary strata, mixed more or less frequently with the materials of the primitive class. They lie above the secon-

[d] Bergmann, Géog. Phys. § 45.

[e] Humboldt, Tableaux des Régions Equatoréales, 118.

[f] See Book vii.

dary strata[a], and are heaped together in a more confused manner.

We will now consider more particularly the composition of the primitive strata.

The roughest, the most elevated, and most extensive mountains of our globe, contain masses of granite, which cannot correctly be called strata, and which very frequently terminate in vast cupolas. Next to these enormous crystals, we see very large and almost vertical banks or ridges of granite, as it were in layers or leaves, and of pure schist, that is, without any mixture of vegetable or animal remains. It is the extremities of those broken masses of laminated granite, which form the most acute and angular peaks. The schist is frequently intersected by numerous metallic veins. Large beds of pure calcareous matter are found in general to run more horizontal, and they give rise to those long ridges of mountains, which are quite free from metals. Masses of porphyry, syenite, and other homogeneous rocks, are generally placed upon one or other of the preceding strata. In America, enormous beds of porphyry repose upon granite, and form the summits of the Cordilleras. Mountains of the first order.

The order which all the primitive rocks observe among themselves, is not yet determined by observation. Granite is almost universally considered as forming a sort of vault surrounding the globe, and supporting all those masses, which seem to have been heaped upon it by the double action of a general crystallization, and a violent jumbling. We have never yet found granite lying upon porphyry, upon schist, or upon any other rock whatever; but the relative order of all the other rocks seems to vary much. The only principle that appears to be determined is, that the primitive or primordial rocks are never placed in great masses upon the others, while the others are constantly found accumulated upon them. Reciprocal order of the primitive strata.

[a] Werner, Classification des Roches, Dresde, 1787. (en All.) Voight, Minéralogie Pratique, 1792, (en All.) See also the works of Saussure, Dolomieu, Humboldt, Deluc, &c. &c.

At the base of these mountains of the first order, and sometimes also at a considerable elevation on their sides, we commonly find calcareous rocks *of transition*, that is, rocks, which in part seem purely calcareous and partly mixed with animal remains. These rocks mark the transition of masses which do not exhibit any regular continued strata, into those rocks which geologists call stratified, the structure of which consists of a series of strata or layers. There are also some other rocks which indicate this transition; these are the recompounded fragments of the pure or primitive rocks, united anew by a species of cement, several varieties of which have been facetiously called pudding-stone, and *amygdaloïdal* or almond rocks, from the appearances which they present.

Transition rocks.

The secondary rocks, formed commonly in regular strata, give a peculiar and characteristic appearance to the mountains which are composed of them. Their outlines are less broken than those of the primary mountains, their summits less lofty; but vegetation displays its richness upon their gently inclined sides of chalk and clay, covered very frequently with a layer of marl, and filled with the remains of animals and vegetables, different from those now existing in a living state. The argillaceous schist bears the marks of an entire vegetation anterior to the present constitution of the globe. In the marly-bituminous schist, we meet with petrified fish and many impressions of aquatic animals; and the calcareous rocks contain the bones of quadrupeds. These three strata, and others which are analagous to them, frequently succeed each other in such a manner, that the remains of the vegetables are placed below, and those of the quadrupeds nearer the surface.

Mountains of the second class, or order.

There are some rocks which follow no regular succession, such as the siliceous sand-stone, (*les grès*[h],) which contains few organic remains, but which, from the diversifi-

[h] "Gres" is translated *silex* or *flint*, and also *free-stone* or *wind-stone*; the latter is the most correct.—T.

ed arrangement of its strata, seem sometimes to approximate to the primitive rocks, and sometimes to those of the most recent formations. Gypsum, (sulphate of lime,) or plaster of Paris, is also a substance, which is met with sometimes in one order of succession, and sometimes in another. Vast masses of it are found among the primitive rocks[1]. What chiefly characterizes stratified mountains, is rock or mineral salt, saline springs, the mineral waters, layers of coppery schist, alumine, calamine, bituminous earths, with petroleum, or rock oil, and naphtha; and lastly, also coal and tar; all these substances are accumulated in layers or beds, the succession of which constantly varies, but which all belong exclusively to stratified mountains. On the other hand, these mountains contain no metallic veins.

In the same manner as the regularly stratified masses are supported by crystallized primitive rocks and are placed upon them, we also see at the bases of those which are composed of strata, mountains covered with earth of a third order, which in fact is also arranged in layers, but without that uniform composition, or that regular cohesion, which make each layer of the stratified rocks a whole of itself. These strata or beds, which we call *tertiary*, are also found in the midst of a confused mass of small portions of substances, which seem to have been accumulated by some fluid, that has transported, or at least rolled and mixed them together. These form the bottoms of valleys, and are almost always placed upon the stratified rocks. *Tufa*, which is formed by the recomposition of the particles of a primitive rock, *conglomerates*, or *breccias*, of the third order, which are heterogeneous compounds of the fragments of rocks united by a cement of tufa, clay, sand, or gravel, are all the principal strata of this kind. Tertiary rocks.

The remains of large quadrupeds and other analogous animals now unknown in a living state, are found in these beds; there also are seen those vast quantities of peat or turf, (*tourbe*,) which are the remains of a recent vegetation

[1] Dolomieu, Journal de Physique, 1794, p. 183.

mixed with bituminous earth. But neither minerals nor metals, either in strata or veins, are met with, except in small detached and separate particles.

Alluvial soils.

In these alluvial or transported soils, as they are too vaguely called, it is natural that the layers of lighter matter should occupy the surface, while the heavier substances should accumulate in the interior. But the former are often seen at very considerable depths, so that there are in alluvions, as in stratifications, many orders of succession. Thus, from the summits of Mount Blanc to the marshes of Holland, and the heaths of Lunebourg, the interior structure of the earth constantly preserves this complicated and enigmatical character, which not only perplexes our reason, but seems to baffle our imagination.

Besides these distinct beds, or strata, the earth presents to us a great number of confused masses.

Pebbles.

All the banks of rivers and lakes, and the shores of the sea, are covered with pebbles, rounded by the waves which have rolled them against each other, and which frequently seem to have brought them from a distance. There are also similar masses of pebbles found at very great elevations, to which the present sea appears never to have been able to reach. We find them in the Alps at Valorsina, more than six thousand feet above the level of the sea; and on the mountain of "Bon-Homme," which is more than a thousand feet higher[k]. There are some places little elevated above the level of the sea, which, like the famous plain of Crau in Provence, are entirely paved with pebbles; while in Norway, near Quedlia, some mountains of a considerable magnitude seem to be completely formed of them, and in such a manner, that the largest pebbles occupy the summit, and their thickness and size diminish as you approach the base[l]. We may include in the number of these confused and irregular heaps, most of the depositions of matter brought by the rivers or sea, and left on the banks, and perhaps even those immense beds of sand which cover the

[k] Saussure, Voyage, § 690.

[l] Bergmann, Geog. Phys. i. 207.

centre of Asia and Africa: And, in general, it may be said, that the third order of beds or layers, very nearly approximate to these confused accumulations. It is this circumstance which renders so uncertain the distinction which it is nevertheless necessary to establish, between alluvial masses created before the commencement of history, and those which we still see forming under our own eyes.

There are, notwithstanding, some substances, the distinct character of which leaves much less room for hypothesis. Such are lavas, the well known productions of volcanos, which are found spread above all other strata around the craters, which have ejected them, like so many streams around one common source. The black-looking torrents of these substances, which have been liquefied by the volcanos now existing, exhibit sometimes shapeless masses, either compact or porous; sometimes they assume the appearance of crystallization, or a separation into laminæ, or into roundish blocks: they are often only one mass of scoria, or ashes, united by a sort of cement, and form what may be called volcanic tufa [m]. The strata or layers, which we observe in lava, and which are commonly separated by thin intervening layers of vegetable mould, indicate the number of volcanic eruptions which have successively produced these different strata. None of these appearances are common to those celebrated substances known under the name of *basalt*, and which many naturalists call primitive lava. This substance, always formed or divided into prisms, is seen in the form of columns, sometimes elevated perpendicularly, as in the cave of Fingal and the Giants' Causeway; sometimes inclined towards the horizon at different angles, as in the Vivarais; sometimes lying horizontally, ranged like logs of wood, and inclosed in fissures, as in the Feroe islands [n], or free and unconnected like the basaltic circle in the island of Mull [o]. But basalt is never placed in large masses upon strata of the third order.

Volcanic lavas.

Basalt.

[m] Faujas Saint-Fond, Essais de Géo. ii. 413, *et seq.*

[n] Memoirs of the Society of Natural History of Copenhagen. See the description of the Feroe Islands. Vol. iv.

[o] Faujas, Géol. ii.

The fragments of granite and other pure rocks, thrown here and there upon stratified rocks, and even upon alluvial lands, exhibit a phenomenon as indisputable as it is astonishing. All the chains of Mount Jura, all the mountains which skirt the Alps, the hills, and even the plains of Germany and Italy, have blocks of granite scattered over them, frequently of large dimensions, and always of as pure a composition, and as beautifully crystallized as the granite of the highest Alps [p]. The same phenomenon is also repeated in the plains of Russia, Poland, Prussia, Denmark and Sweden. From Holstein to eastern Prussia, upon the alluvial lands, of sand and clay, an immense number of blocks of granite are found. Near the island of Usedom, many detached masses of granite rise up from the bottom of the Baltic [q]. We see the same thing in Scania and in Jutland, which are so full of these fragments, that they use them for inclosures, for houses and churches. These blocks are rounded by the action of the heavy rains. In Lymfiord, a gulf of Jutland, and at some points on the western coast of that peninsula, sharp peaks of granite shoot up from the bottom of the sea. But what is most remarkable, is to see enormous masses of granite placed upon the summits of the calcareous mountains of Rettwick, of Roedaberg and of Osmund, which are near six thousand feet above the level of the sea, and which consequently are among the highest mountains in the north of Europe [r].

Blocks of pure granite.

If this phenomenon has not been noticed in all the regions of the globe, we must perhaps attribute it to the few observations which travellers have made upon this subject.

Conclusion.

The structure of the globe, of which we have been endeavouring to trace the grand features, presents in all its parts the appearance of a vast ruin; the confusion and overthrow of most of its strata, the irregular succession of those which seem to remain in their original situations, the

[p] Delamétherie, Théorie de la Terre, § 1188, *qqq.* Ferber, Dolomieu, &c.
[q] Wrede, dans *Zach.* Correspond. v. 456.
[r] Bergmann, Géog. Phy. i. 265.

wonderful variety which the direction of the veins and the forms of the caverns display, the immense heaps of confused and broken substances, the transportation of enormous blocks to a great distance from the mountains of which they appear to have formed a part, every thing, in short, makes us feel that the history of our globe reaches back to periods far anterior to the existence of the human race, and that the researches which are necessary to bring us acquainted even with the present state of its surface, (and scarcely beyond the surface can we penetrate,) would require a length of time, and an amount of expense hardly to be calculated, before our observations could be so matured and verified as to form the foundations of a complete scientific whole.

BOOK IX.

Continuation of the Theory of Geography. Of simple Substances which compose the solid part of the Globe. First Section: Saline, earthy, and inflammable substances.

It belongs to chemistry to examine in what manner the gases, the acids, and the elementary earths, have acted in the formation of the non-organic substances which form the solid crust or surface of our globe, and of which we are now going to consider the external and internal forms. Mineralogy describes, defines, and classifies these substances; geology treats of their origin; but physical geography, the object of which is to investigate the structure, composition, and physical relations of the globe, cannot be accused of going beyond its limits, in tracing out a general view of the various substances of which the solid parts of the earth are formed.

Definition of simple aggregate substances.

These substances are either *simple*, that is, formed of the same chemical elements, and having for their nucleus the same integrant molecule; or *aggregate*, that is, composed of two or more simple substances. The first of these substances are minerals, the objects of the sciences of mineralogy and crystallography; the second are the rocks and earths, which belong to the province of geognosy.

Classification of minerals.

We distinguish four classes in the mineral kingdom: the first comprehends saline or *acidiferous* substances, which are composed of an acid united to an earth or an alkali, and sometimes to both. The second contains the *earthy* substance, into the composition of which earths alone enter, or sometimes an earth united to an alkali; in the third class are placed all *inflammable* substances which are

not metallic; substances hitherto imperfectly analyzed, but which may be distinguished by the property which they possess, of burning, or of evaporating, when decomposed. The fourth class embraces the *metallic* substances known by their brilliancy, by their great specific gravity, and, in part, by their ductility and malleability [a].

We shall now consider the mineral kingdom, in so far as it regards physical geography, that is, by examining the genera most abundant in nature, and the species most remarkable for their physical qualities. While we take the Terminology of M. Haüy for the basis, we shall compare it with that of other mineralogists.

Carbonate of lime.

The carbonate of lime, that is, lime combined with carbonic acid, is also called aerated lime, or calcareous spar. It is the most abundant of any known mineral substance on the earth. It belongs to every geological epoch, and to every soil. Among the ancient and primordial masses, it not only forms one of the constituent principles of rocks, but it also is seen in its pure state in immense beds or banks, the peculiar character of which is a laminated or scaly texture, which indicates a confused crystallization. It abounds still more in the secondary or stratified mountains and masses of earth, of which it forms more than the half. It is found also in the third order, combined with clay, and thus constitutes the various marls. It forms also vast beds in the state of chalk, frequently accompanied by large masses of calcareous shells compressed together, and broken, and which had once been inhabited by marine animals. We are therefore led to consider chalk as a very ancient chemical decomposition of the altered and obliterated remains of shell-fish [b]. It is well known that the madrepores and other polypi of the equatorial seas, form chalk continually in great quantities. The port of Bantam was shut

Tale.

[a] Haüy, Traité de Minéralogie. Brongniart, Traité Elem. de Minéralogie. Delamétherie, &c.

[b] Steffen's Memoir upon the Natural History of the Interior of the Globe, p. 26. (In German.)

up in less than a century by rocks of coral formed by polypi[c]. Limestone is discovered mixed with flints and coloured marbles *(brèche)* in alluvial soils, and also in volcanic soils, where it has been detected by the explosions that have taken place. There are, however, countries where chalk is not found; where, at least, it has hitherto been but very rarely seen; as, for instance, in the neighbourhood of the Cape of Good Hope[d], and in the granite and volcanic peninsula of Kamtchatka[e].

The carbonate of lime confusedly crystallized, forms the building materials in France. When it possesses a finer grain, it forms a sort of marble of no great value. According as it becomes harder, and, if we may so express it, more refined, it takes a much finer polish, and is better fitted for the chisel of the sculptor. It is then properly called marble. White statuary marble from Carrara in Italy, is esteemed the purest of any. The coloured marbles are formed of calcareous matter, mixed more or less with extraneous substances. Pliny is right when he says, "Every country possesses its peculiar species of marble." Marbles, however, more regularly crystallized, of a larger grain, and more mixed with particles of pyrites, become more rare as you leave the middle of the temperate zone, and approach the pole.

Marble.

Crystals of carbonated lime, under the name of calcareous spar, are found in almost every subterraneous cavity, and in all veins. They serve to ornament every cabinet of mineralogy. Filtering through the vaulted roofs of subterranean grottos, this substance forms those concretions known by the name of calcareous stalactites; the various positions and forms of which present all kinds of agreeable and fantastic appearances to the imagination of the spectator. The eagle-stone *(géode)* is a concretion, the interior

Calcareous spar.

Stalactites.

[c] Blumenbach, Histoire Naturelle, p. 450. Comp. Forster, Péron, &c.

[d] Thunberg's Travels, i. 216. (In German.) Sparman's Travels, 142—618. (In German.)

[e] Georgi, Description Physique de la Russie, I.

of which is hollow, sometimes filled up with crystals, sometimes bristled with multitudes of needles. The more abundant and uniform calcareous concretion produces those masses known under the name of calcareous alabaster, which differs from marble in being less pure, more variegated in its colours, and somewhat more transparent. Calcareous alabaster.

The incrustations which are formed by water, loaded with carbonate of lime, have led to the supposition that there are some petrifying springs. These incrustations preserve exactly the figure of the vegetables that have been covered with them, the substance of which has been destroyed. It is in the same manner that the tufas are formed, or calcareous sediments in canals, and the beds of rivers and lakes, the waters of which are charged with this substance. Incrustations.

Other species of lime are of less importance, Some varieties of phosphated and of fluated lime exhibit coloured crystals, which very much resemble the more precious stones, such as chrysolites, emeralds, rubies, and others. Fluated lime is often found in the matter of metallic veins, mixed with the ore. Phosphated and fluated lime.

Sulphated lime, or lime combined with sulphuric acid, is commonly called gypsum, or plaster-stone, when mixed with carbonated lime. When crystallized, it is called selenite. This stone is divisible into brilliant and transparent laminæ, and was used by the ancients instead of glass for windows. It very much resembles the foliated *mica*, or talc of Muscovy, yet is totally different in regard to the nature of its component parts. The compact sulphated lime, fine and close-grained, and of a beautiful white colour, is the substance which, under the name of gypseous alabaster, or alabastrite, (pseudo alabaster,) has so often afforded the poets a term of comparison to express the whiteness of the neck or arms: "A skin as alabaster pure." Sulphated lime is often found under the form of hills or little mountains, and sometimes in beds or strata, in countries of the second and third formation. It is doubtful whether there be any of the first formation, or whether Sulphated lime. Gypseous alabaster.

the heaps which are known to be among the primitive mountains, have not been produced by causes of a later origin [f]. The school of Werner supports the first opinion. The north of Europe and of Asia furnishes very little sulphate of lime [g].

Barytes. Strontites.

Barytes and strontites are but of little importance in a physico-geographical point of view, although the sulphated variety of the latter affords those magnificent crystals which are found in the cavities of the mines of sulphur in the valleys of Noto and of Mazzara in Sicily. To what extent magnesia is concerned in the formation of certain rocks, is not yet sufficiently determined [h]. The sulphate of magnesia, known under the names of *sel amer* and Epsom salt, is found in many mineral waters, particularly all those in the neighbourhood of Montpelier. It is also found in a state of efflorescence upon the surface of schist, from which it can be easily collected [i].

Magnesia.

Nitrate of potass.

Nitrate of potass is composed of vegetable alkali or potass, nitric acid, and the water necessary for its crystallization. It is generally known under the name of saltpetre, or nitre. It is constantly formed in those places which, like our stables and cellars, contain animal and vegetable matters in a state of putrefaction, or which receive the effluvia of those substances. It is deposited upon the surface of old walls. As this article is much used in the manufacture of gunpowder and aquafortis, or nitric acid, they make artificial nitre beds by means of a mixture of vegetable and animal substances.

Muriate of soda, or common salt.

Muriate of soda, or common salt, is composed of soda, muriatic acid, and water. It is spread throughout nature in an abundance corresponding to its extensive utility. When found in a crystallized state, it is called fossil, or rock-salt. There are immense masses of it in Poland, in Hungary [k],

[f] Saussure, Voyage dans les Alpes, § 1208, 1226, 1239, 1931.

[g] Georgi, Description Physique de la Russie, v. 126.

[h] Faujas Saint Fond, Géologie, ii. 298, *sqq.* Delemétherie, Theorie, v. p. 12.

[i] Chaptal, cité par Haüy, Minéralogie, ii. 336.

[k] Fichtel, History of Rock-Salt. (In German.)

in Austria, in Bavaria, in Hanover, in England, in Spain, and generally in all secondary countries. Great quantities of this salt are held in solution by the water of the ocean, from which it is procured by various processes. Sea water is sometimes evaporated in shallow ditches or pits by the action of the sun; sometimes in large vessels, by the aid of fire, and the salt procured from it has different degrees of sharpness and strength. Some lakes, rivers, and springs, contain salt, particularly in the neighbourhood of the Caspian sea, where even the soil is impregnated with it. Salt lakes are generally found near hills of marl, clay, limestone, and gypsum [l].

The borate, or rather sub-borate of soda, or borax, is of great utility, especially in the melting and soldering of metals. This substance, the origin of which is disputed, is found as a native production in some lakes and caverns in Thibet, Nepaul, Persia, Tartary, and in Saxony, but we also obtain it by a method similar to that employed for procuring nitre[m]. Carbonate of soda, commonly called natron, is found in certain lakes in Egypt; in that of Kis-Maria in Hungary, and in those situated in the plains north of the Caspian. It sometimes covers the plains with a slight efflorescence [n]. The muriate of ammonia, commonly called sal ammoniac, comes from Egypt and Persia. It is also found in small quantities round the volcanos of Sicily and Italy. It is also made in several countries in Europe. Mixed with pounded ice, it produces an artificial cold, which, according to Macquer, reaches to 18 degrees below zero in Reaumur's thermometer [o]. All these salts seem more particularly to abound in plains, which are surrounded by mountains; and which must have been the basins of lakes that are now become dry, or partly run out. The

Borax.

Carbonate of soda.

Muriate of ammonia.

[l] Pallas, Voyag passim. Georgi, Descript. de la Russie, v. 21. 59.

[m] Fourcroy, Elémens d'Histoire naturelle et de Chimie, tome ii. p. 68. Busching, Introduction à la Géographie, p. 120.

[n] Voyages de Townson, de Pallas, etc.

[o] That is —8⅘ or 40½ below the freezing point, in the common or Fahrenheit's thermometer.

great desert of Sahara appears to be a similar basin, covered with saline efflorescence, while the country watered by the Niger is totally free from it. Brazil, in America, is destitute of salt, while Paraguay abounds with it. This salt is rare in Scandinavia, and in the north of Russia.

Alum. Alum, in recent chemical works, is called alkaline-sulphurated alumina. This substance is found by itself only in very small quantities; but it can be procured from certain earths and stones, which are impregnated with it, or from schists and pyrites, which contain only its principles.

Pure alumina[p], or earth of alum, which is procured from alum, is distinguished among the elementary earths by its tendency to mix and unite itself with water. It is found blended with the most dissimilar substances. It enters into the composition of common clay, and into that of oriental gems. We know that these stones are very difficult to melt.

Cryolite. A Danish missionary has brought from Greenland a substance, which has been called cryolite, and which melts like ice in the flame of a candle; it is the fluated alkaline alumina of Haüy. These very opposite results from combinations, in which the same substance is predominant, ought to teach us, that in forming a true theory of the earth, we should employ with the utmost circumspection the principles and analysis which chemistry affords.

Quartz. Let us now proceed to earthy substances. The first species which offers itself to our attention is that of hyaline quartz, or quartz properly so called. This has crystallized silex for its base, and comprehends some varieties very different in their aspect to the eye of the ignorant; but the severe method of modern mineralogy, established upon chemical analysis, rejects all false classifications founded upon external appearances.

When hyaline quartz[q] is found in round or angular

[p] It is called Alumina, from its being the base of the salt called alum, and sometimes argil, because it is also the base of the clays.—T.

[q] Haüy, ii. 107, *sqq.*

grain, without cohesion, having a vitreous surface, it is es- Sand and gravel.
teemed of no value, being nothing but sand or gravel, and fit to be used only in the formation of roads: if these small grains are united by a natural cement, they form silicious quartz, (*grès quartzeux.*) When the same substance has by natural friction been fashioned into small round masses, it is raised into the rank of crystalline flints, (*cailloux cristallins.*) Lastly, when hyaline quartz, in consequence of a more regular crystallization, is of uniform density, and perfectly transparent, it occupies a distinguished place in the collections of amateurs under the name of rock crystal; it ornaments our lustres; is used even in some kinds of jewellery. In Madagascar, these crystals are found in the greatest purity, and in large tables or flat layers[r], and this seems to confirm the truth of the reports mentioned by Herodotus and Pliny, of the abundance of crystal in Upper Ethiopia. When of a violet or purple colour, the rock crys- Rock crystal.
tal becomes amethyst, and is in this state highly valued and classed among the gems. When blue, it is the sapphire, (*saphir d'eau,*) which is not so precious: When it assumes the colour of rose, it is the ruby of Bohemia, the most valuable of all: when yellow it is the occidental topaz; in short, the crystals of this substance take the names of the different gems which they resemble in colour.

The species of quartz agate, of which concreted silex constitutes the base, and of which many mineralogists still continue to form a distinct genus under the name of *silex*[s], Silex.
contains the following among other varieties; the chalcedony, which is of a bluish or grey colour, and of an imperfect and cloudy transparency; the cornaline, which is red, and of a cherry-like semi-transparency, and sometimes of a beautiful carnation hue; and lastly, the chrysoprase, a stone of a delicate and clear green. They give the name of onyx to agates formed of two translucid stripes of different colours. Oriental agate is distinguished by the fineness of Oriental agate.

[r] Rochon, Recueil de Mém. sur la Physique, 155.

[s] Comp. Haüy, ii. 439. Bergmann, Sciagraphia, i. 325. Delametherie, Théorie de la Terre, ii. 136.

its composition, and by the peculiar appearance given to its interior by its various undulated laminæ.

When the quartz agate is less fine in its composition, it is used for gun-flints and for mill-stones, and even for common flints. The enhydros, celebrated by Pliny, is only an eagle stone, of quartz-agate, containing a small quantity of water, which is perceptible through the semitransparency of the stone. There is a variety of quartz, which floats upon the water until it has imbibed a certain quantity.

Opal. The noble or perfect opal, as it is termed, is a milky resinous quartz, exhibiting a beautiful play of colours, like those in the rainbow, and varying their shades according to the position. It is highly prized on account of this brilliant appearance, which, however, arises solely from imperfections, that is, very minute cracks or fissures with which it is filled. When divided, it no longer displays this pleasing and changeable effulgence[t]. The hydrophane, or semi-opal, becomes of a beautiful transparency, when plunged in water.

Jasper. Jasper is a quartz agate, blended with argil or clay, and a little iron, which gives it a variety of colours. It was formerly confounded with porphyry; but, it is now ascertained that jasper is of a secondary formation, and has nothing in common with the primitive rocks of porphyry. In general all quartz agates belong to the secondary earths.

Common silex. The beds of silex, properly so called, namely, gun-flints, mill-stones, and common flint-stones, though inconsiderable in regard to the whole globe, present, in respect of their situation, some remarkable peculiarities. Strata of silex very often alternate with those of chalk. Hence some naturalists have thought that they were the petrified remains of certain marine animals[u]. In several vast regions of the globe, as, for example, Siberia, and the plains in the neighbourhood of the Caspian Sea, gun-flints or "silex pyromaque"[x] is very seldom found.

[t] See Newton, Optice Lucis, l. ii. p. 2. and the Minéralogie of Haüy, ii. p. 456.

[u] Delamétherie, Théorie de la Terre, v. 33.

[x] Georgi, Description de la Russie, iii. 169.

Hyaline quartz, without ever forming the entire substance of any mountain, abounds in every soil. It is one of the integral parts of most varieties of the granite rocks. It also enters, in the form of crystallized grains, into the composition of many rocks of porphyry. It forms the base of a great number of fossil micaceous rocks. Its crystals occupy the fortuitous cavities which are found in almost all the large masses of rocks. They ornament the walls or sides of such cavities, sometimes in transparent prisms of nearly a foot in diameter. Hyaline quartz forms veins, frequently of a great extent, which pass through the primitive mountains; and these veins, becoming exposed, and projecting by the wearing away of the rocks in which they were imbedded, have given rise to the opinion, that there existed mountains entirely composed of quartz. There is scarcely any secondary rock, in which we do not find common or unshapen quartz, in masses, in veins, or in crystals [y]. Situation of hyaline quartz.

Arenaceous quartz, *(quartz arénacé,)* or quartz in the form of sand, covers almost entirely the bottom of the sea. It is spread over the banks of rivers, and forms vast plains, even at a very considerable elevation above the level of the sea, as the desert of Sahara in Africa, of Kobi in Asia, and many others. This quartz is produced, at least in part, from the disintegration of the primitive granite rocks. The currents of water carry it along, and when it is in very small, light, and rounded grains, even the wind transports it from one place to another. The hills thus are made to move like the waves, and a deluge of sand frequently inundates the neighbouring country [z]. Situation of arenated quartz.

Arenaceous quartz furnishes, by fusion, one of the most useful substances we have, namely, glass, which, being less hard than the crystals of quartz, can be made equally transparent, and is equally serviceable to our wants and to our pleasures. There it shines in walls of crystal in the palaces

[y] Brongniart, ii. 271—279.

[z] So where o'er wide Numidian wastes extend,
Sudden the impetuous hurricanes descend, &c.—See *Addison's Cato.*

of the great, reflecting the charms of a hundred assembled beauties; here, in the hand of the philosopher, it discovers to us the worlds that revolve above us in the immensity of space, and the no less astonishing wonders that we tread beneath our feet.

Precious stones.

We shall now shortly notice the different species of precious stones, which are almost all composed of alumine, or pure argil, as the analysis of Bergmann and Klaproth have proved. According to the method of Haüy, the name of *Corundum* now comprehends a species, the red variety of which is the true oriental ruby[a]; the blue, the oriental sapphire; and, the yellow, the oriental topaz. These three varieties are comprehended by the French amateurs under the general name of "oriental gems." These valuable and brilliant substances consist of ninety-eight parts of alumina, and two of iron. To the species called by the French

Spinelle.

Spinelle, the colouring matter of which is the metal called chrome, belong the scarlet or light red ruby, the pale rose or pink ruby, the variety, called *rubacelle*, of a yellowish red colour: all these are less hard, and have less play or

Topaz.

brilliancy than the corundums. The limpid and transparent topazes of Siberia, the pale yellow ones of Saxony, those of Brazil, the colour of which is a reddish yellow, are all included by Haüy in the same class. The ruby of Brazil is only a red topaz, (sometimes reddened by means of fire,) the beryl or oriental *aigue marine*, called the sapphire of Brazil, is a greenish blue topaz. Many chrysolites be-

Emerald.

long to the same species. The beautiful emerald of Peru, the pure green of which is more pleasant to the eye than the dazzling brilliancy of many other more perfect gems; and the occidental or common beryl, a stone of but little value, have both the same bases, namely, silex, alumina, glucine, and lime; but the colouring principle in the emerald is chrome, and, in the beryl, a very small quantity of

Garnet.

iron. The garnets of Bohemia, of a deep bright red, and

[a] Lapidaries call all perfect gems oriental, and those which are less so occidental.

those of Syria, of a purple violet colour, contain a large proportion of iron, sometimes one-third, or even two-fifths: the oriental garnet is very magnetic. It is a singular circumstance, that this quantity of iron does not injure its transparency [b]. The *cymophane*, known also by the names of chrysoberyl, and oriental chrysolite, is of a yellowish green colour, and is nearly as hard and heavy as the corundum.

We have not yet spoken of the diamond, that king of gems. The reason is, that this king is now dethroned. Modern chemistry has proved, by multiplied and decisive experiments, that the diamond, far from resisting the fire, like all true gems, is entirely dissipated, without leaving any residuum whatsoever. Consequently, the diamond is now classed among the combustible substances, along with sulphur, amber, and coal. It appears that the diamond consists of pure carbon. Like all the other fine gems, the diamond seems to abound most in the East Indies, and in South America. The precious metals also more peculiarly belong to the equatorial regions. Diamond.

Passing over some less interesting species, we come to feldspar, a substance composed principally of silex and alumina, with small proportions of lime and potash. If it be coloured, it is by the presence of oxide of iron. It cuts glass, is phosphoric, and emits sparks when struck with steel. The feldspar forms the base of a multitude of rocks, and predominates in those of primitive formation, constituting at least two thirds of the substance of granite [c]. Extensive mountains are sometimes solely composed of it. Guldenstedt tells us, that feldspar, either pure, or mixed with granulated quartz, forms that vast plain of rocks, which extends from both sides of the cataracts of the Dnieper. The fosses of the fort of Sacharowa, are cut out of natural feldspar [d]. It is also to this substance that porphyry rocks owe the distinct spots which arise out of Feldspar.

[b] Haüy, ii. 551.

[c] Dolomieu, quoted by Haüy, ii. 604.

[d] Georgi, Russie, iii. 179.

their general colour; but these rocks rarely present themselves under regular forms. The fine crystals of feldspar, whether opaque and coloured, or limpid and transparent, occupy veins or cavities, contained in the primitive mountains; and it is the Lombard Alps which have furnished what the cabinets of France consider the most perfect specimens of this kind. But the most beautiful crystals of feldspar, which join to a fine green colour a great degree of transparency, are found in detached blocks or masses in the steppes of the Kirguis, whence the Bucharians carry them to Semipalatnoi [e]. It is the mountains of Siberia, towards the lake Baïkal, which have supplied these large plates of azure feldspar, with which the palace of Czarskoselo is adorned. It appears then that this substance abounds still more in the Alps of Asia than in those of Europe. On the contrary, America does not appear to afford it in large quantities.

Decomposed feldspar.

Feldspar, even when decomposed, still maintains a character of importance. It is found in extensive beds, from the Uralian mountains to Kamtchatka. Of the two substances which the Chinese use in the making of porcelain, the one named *petunzé*, is a whitish laminated feldspar; the other called *kaolin*, is an argiliform feldspar, that is to say, feldspar which has passed by decomposition, from the state of a stone, to that of a very brittle clay, without cohesion, combining with water, of a fine white colour, and infusible by itself—the *petunzé* acting as a flux. The same substances are employed in Europe in the manufacture of porcelain ware.

Petrosilex.

The name of *petrosilex* [f] has been given to several substances, very widely distributed in nature; but there appears to exist great confusion in this subdivision of the mineral kingdom. The hornstone of Werner or keratolithe

[e] Pallas, Nouv. Mémoires du Nord, v. 309. Bindheim, Analyse, etc. dans les Mémoires des Naturalistes de Berlin, vol. xi.

[f] Petrosilex, a Latin word, which corresponds to the words, *fels-kisel* in German; *berg-flint* in Danish; *helle-flinta* in Swedish: all these words mean rock-flint.

of Delamétherie, and the secondary petrosilex, or *néopètre* of Saussure, appear to be one and the same substance [g], belonging to the larger *quartz agates*, and to the secondary rocks; but the true petrosilex, compact and semi-transparent, which is found in Sweden [h], in Norway, in Switzerland, and in general in all the primitive rocks, appears to resemble feldspar [i]. This stone forms of itself very considerable mountains, as well in the Alps as in the Uralian chain. In the latter, it is found sparingly in detached blocks and rolled pebbles. *Amphibole*, though less common than feldspar, holds a no less distinguished rank among the substances which compose the primitive rocks. It predominates in greenstein; it forms with feldspar the primitive trapps, which differ from basalt; and enters into the composition of syenite, a stone often nearly allied to granite. It also forms of itself very considerable masses. The crystals of European amphibole are most frequently met with incased in substances ejected by volcanos. In Siberia, the traveller Laxman, found, near the lake of Baïkal, amphibole crystallized in small prismatic columns, with four large faces, and three small ones. It was hence called baïkalite [k].

Amphibole, once called Hornblende.

Mica, a substance remarkable for its metallic brilliancy, is distinguished from talc by its pure, smooth surface, and by not being like talc unctuous to the touch. The variety of mica which consists of large thin transparent laminæ, is mistermed talc of Muscovy. It is also known under the Latin name of *Glacies Mariæ*. The Russians, especially in Siberia, use it in their windows instead of glass [l]; but it soon becomes soiled, and, in some measure loses its trans-

Mica.

Glass of Muscovy.

[g] Voyages, § 1194.

[h] Wallerius, Sytème Minéral, vol. i. p. 283. (Petrosilex æquabilis, Spec. 122.)

[i] Haüy, iv. 385. Delamétherie, ii. 203.

[k] Severgin, Nov. Act. Petropol. 1791. p. 307. Crell, Chim. Ann. 1793. ii. 21.

[l] Patrin, Hist. Nat. des Minéraux, vol. i. p. 71.

parency by exposure to the air. Another variety of mica in spangles of a yellowish gold, or whitish silver colour, is known all over the world, by the ridiculous names of cat's gold, or cat's silver. The gilt sand, and gold powder, which the paper-makers use for purposes of ornament, are only mica in small fragments.

Position of mica.

Mica, says Dolomieu[m], belongs essentially to the primordial rocks, where it has originated in the midst of the confused crystallization by which these rocks have been formed. That which is imbedded in certain stony substances, of secondary formation, has been conveyed thither after the destruction of the rocks which inclosed it; and so much the more easily, as its particles, thin and light, were susceptible of being carried along by the waters, which deposited them with other sediments of an analogous nature. The remains of mica, are also found (having been carried thither) in the beds of hard grey-stone, *(grès)* and schist, which generally alternate with strata of coal. Its fragments are still often disseminated in the sands of the most recent epoch; thus it exists in different states in substances of every formation. It appears that, in the south of Europe, as has been well observed by Dolomieu, mica is rarely found crystallized by itself; that in rocks it does not form laminæ of any sensible extent, and that, even in the state of veins, its plates are only some inches in dimensions; but all accounts agree in asserting that it is found in Russia, Siberia, and Songoria, in laminæ, and in masses, sometimes more than two ells square. It is in the granite mountains near the rivers of Mama and Aldon that the mica is worked. It is found in detached masses, and it sometimes appears on the surface of the earth, but is oftener covered with a bed of talc[n]. Near the lake Baïkal, and in the Uralian mountains, we meet with masses composed of rhomboidal and hexagonal laminæ of transparent mica in the midst of granite. It is

[m] Haüy, Minéralogie, iii. 211.

[n] Gmelin, dans Georgi, iii. 238.

an undoubted phenomenon in physical geography, that the most abundant crystallization of mica is in the northern regions.

Talc,[o] which differs from mica by the greasiness of its surface, is also less hard; it does not even mark the carbonate of lime; it is easily scraped with a knife. On the other hand, it differs from soapy clay, because it forms no paste with water, and does not adhere to the tongue. The talc of Venice, which abounds in the Tyrol and Valteline, is of a greenish white, silvery, and divisible into thin, transparent, and flexible plates; it furnishes a powder which renders the skin smooth, and is employed as a cosmetic. The scaly talc is known under the name of chalk of Briançon. *Steatite*, or Rock Soap, is the graphic talc of Haüy. It is the substance of which these little figures that are brought from China are formed, and whose grotesque appearance has caused them to be called *Magots*, in allusion to a species of monkey which bears that name. The "talc ollaire," which is easily turned on the wheel, is made into pots. Talc.

This substance belongs equally to the primitive and secondary rocks, but it is less common in the latter. According to Dolomieu, it sometimes arises from the decomposition of serpentine rocks, and it then occupies cavities where the products of the decomposition are collected. Dolomieu, however, considers the talc as formed a long time after the granite rocks. It indeed is disposed in very extensive banks, but then it is neither pure nor homogeneous. The purest talc is found in detached nodules imbedded in micaceous rocks. The open chlorite talc, seems sometimes to have penetrated by filtration into the veins of the primitive rocks; it is coloured by iron. In Corsica, and near the White Sea[p], we find a foliated sort, which is penetrated throughout with little sparkling crystals of iron. The green earth of Verona, which is used in painting, is a Position of talc.

[o] Talc, a stone greasy to the touch and sight; from talg, *fat*, in Danish, Swedish, German.

[p] Laxman, in Georgi, iii. 211.

variety of chlorite talc; it is contained in beds of compact lava, into the cavities of which it has been introduced by filtration.

Tourmaline. We shall be obliged to pass rapidly over many interesting species, such as the tourmaline or the electric schorl, which is remarkable for its very strong electricity in its two opposite points; when heated, it attracts or repels light bodies, such as ashes[q];—the lazulite, or sapphire of the ancients[r], which furnishes the superb paint called Ultramarine, the permanency of which, by the side of the other colours, which are more or less affected and altered by the action of the air, somewhat impairs that harmony of tints which is so pleasing in pictures;—a number of stones, to which the names have successfully been given, of *zeolite*, *jade*, or nephrite, which resembles talc; idocrase, otherwise vesuvian; the *amphigene* of Haüy, otherwise the leucite or white garnet; the *emeraudine*, (*dioptaze* of Haüy,) which, by its beautiful green colour, derived from copper, indicates the emerald species; and a number of others, which it were tedious to enumerate. We will terminate this hasty survey of earthy substances by a brief description of the celebrated asbestos.

Lazulite.

Jade.

Asbestos, or amianthus. This substance, called also amianthus, appears to be produced from the decomposition of primitive rocks, amongst which it is oftenest found. It chiefly occupies fissures and cavities of steatitic rocks, serpentine, and others abounding in magnesia. The asbestos which is found in the mountains of Tarantaise, in Savoy, forms silky filaments of more than three decimetres, or about a foot in length. People, when they see, for the first time, a detached tuft of asbestos, can scarcely be convinced that it is actually a stone, and not a species of fine white silk. Asbestos abounds in Corsica; Dolomieu made use of it, instead of hay and tow, to pack up other minerals. Ciampini says, that the longest asbestos

[q] Minéralogie de Haüy, iii. pages 44—58.

[r] Bayer, Dissert. de Sapphiro. Beckmann, Histoire des Inventions, iii. 182. *sqq.*

he ever saw came from the Pyrenees [s]. It abounds in the Uralian mountains, and in Greenland. In Corsica, they mix asbestos with the clay used in the potteries, which is thus rendered less brittle, and more capable of resisting the sudden alternations of heat and cold. The ancients spun the asbestos, and made towels, napkins, and head dresses of it. When these became soiled by use, they were thrown into the fire, which did not destroy the substance of the asbestos, and upon being taken out, were found to be whiter than if they had been washed. In the funeral obsequies of kings and emperors, the dead body was enveloped with cloths of asbestos, before it was placed on the funeral pile; and thus the ashes were obtained quite unmixed [t]. In modern times, the Russians alone have attempted, but without success, to spin the asbestos. The inhabitants of the Uralian mountains have still preserved some remains of this frivolous industry [u]. The indestructible paper, made from this substance, appears more useful. Wicks for lamps are also formed of the asbestos, which easily imbibe oil, and burn with a brilliant flame [x]. Father Kircher made use of such a wick for more than two years, without any perceptible decay, but, having wet it by accident, was prevented from continuing his experiment. Perhaps the fabulous accounts of unextinguishable sepulchral lamps derive their origin from this circumstance.

Use of the asbestos.

Of the inflammable substances, sulphur naturally presents itself first to our observation. That which is crystallized by the action of a liquid, is found in veins or in beds, amongst sulphate of lime, or amongst potters clay. These beds, which are often very extensive, border upon strata of rock salt. Crystals of sulphur sometimes adorn the interior of calcareous, or even quartz eagle stones. With respect to sulphur formed by sublimation, it is found in powder, in striated masses, or even in crystals, at the mouth

Sulphur.

[s] De Lino Incombustibile; Romæ, in 4to. 1691, p. 5, 6.

[t] Pliny, Nat. Hist. b. 19. ch. 1.

[u] Bruckmann, Magnalia Dei in locis subterr. ii. 955. Georgi, iii. 244

[x] Egede, Account of Greenland, (in Danish.)

of many volcanos, such as Etna, Vesuvius, and Mount Hecla. Sulphur is also obtained from the putrefaction of animal matter. Several substances, amongst others the sulphurous pyrites, are impregnated with sulphur. We cannot doubt that sulphurous and sulphuric acid exerted a powerful agency in the primitive fermentation of the elements—but there is nothing in the existing economy of nature which can enable us to penetrate these mysteries of "chaos and ancient night."

We have already spoken of the diamond, to which the rigid justice of modern chemistry assigns a place amongst combustible substances. The anthracite, a substance similar to the pit coal, combined with stony matter, of difficult combustion, appears to have the same principle for its basis as the diamond, namely, pure carbon, accidentally mixed with flint and iron. The anthracite occurs chiefly, but not exclusively [y], in primitive rocks, where it forms considerable masses. Thus, as Dolomieu observes [z], "carbon, or the carbonaceous principle, exists in nature, independently of animals and vegetables, of which there are no traces found in the primitive soils." Let us also add, that sulphur must have existed before organized bodies, since, as Delamétherie observes, it is found in granite [a]. Deluc has lately expressed the same opinion in relation to primitive calcareous earth [b]. We seem every day becoming more disposed to admit the formal pre-existence of all the elements which enter into the composition of the globe, whilst false logic would represent them as being wholly the remains of animals or vegetables. Let us rather say, that the organic energy of nature exerted in two different directions, has given rise on one side to calcareous rocks, alkaline-earthy substances, and animals—on the other, to quartzeous and bituminous substances, and vegetables; constantly putting in action the same elements, or their

Anthracite.

Carbon.

[y] Hericart de Thury; quoted by Brongniart, Tr. de Minéral. ii. 58.

[z] Journal des Mines, No. 29. p. 338, 339.

[a] Théorie de la Terre, ii. p. 250.

[b] Journal de Phys. 1803.

products, but always proceeding from a general and imperfect organization, to another more individual and more perfect, ascending from the stone to the diamond, from molybdena to gold, from the medusa to the shell, and from the polypus to man.

The elementary oils existed also without doubt before vegetable substances. The place they hold in nature is worthy of our attention.

Bituminous petroleum.

Bitumen, in a liquid state, when it is of a brownish colour, commonly bears the name of petroleum, or mineral tar, and when it is white and transparent, that of naphtha. It filters through the earth and rocks which remain impregnated with it. There are springs of it; those of Baku in Persia are well known. It floats sometimes like oil upon the surface of the waters. It is said that there is a lake of this description in Mesopotamia. In the duchy of Parma, it is drawn up in buckets from wells sunk in the earth for the purpose. The same substance, in drying, passes to a state of glutinous bitumen, named also *maltha*, mineral pitch, or *pissasphaltum*, and from that to solid pitch—in this last state it is called *asphaltum*, and gives its name to lake *Asphaltus* in Palestine. It appears that a subterraneous fermentation detaches from a bed of solid bitumen, situated under the lake, those crusts of asphaltum that we see swimming on its surface. The glutinous bitumen is found in France, in Auvergne, at a place called the Puy de la Pége[a], where it covers the earth, and sticks to the feet, so as to incommode and retard the traveller. In Persia, Japan, and other countries, they use liquid bitumen as oil for their lamps. The Persians and Turks mix it with their varnish to give it lustre. The walls of Babylon were built with a cement in which bitumen formed an ingredient. Rouille has concluded, from his experiments upon mummies, that the Egyptians employed bitumen in their embalming.

[a] Lémery, Dictionn. p. 602. The name of *La Pege* comes without doubt from the Latin *pix*, *picis*, la *poix*, pitch.

Pitcoal.

Pit-coal appears to be bitumen united to an earthy base. Most naturalists consider pit-coal, (and the same may be said of other bituminous substances,) as being in a great measure a product of the vegetable and animal kingdoms. Such an origin appears at first marked out by the numerous remains of organic bodies, particularly of well known sea animals, which are found in coal mines; by the impression of different plants, particularly of the fern tribe, in the schistous clays, which form the roof of these mines; and, finally, by wood, still partly in a ligneous state and partly bituminated, so that we can, from such appearances trace, as it were, the process followed in the formation of coal, from one point in the scale to another.

Chemical analysis proves that pit coal gives the same products as organized bodies, namely, hydrogen, oxygen, carbon, azote, and an earthy residue.

Position of pit-coal.

Coal is most commonly found in France and in England, where the primitive and secondary rocks join; whence it has been concluded, that beds of coal were collections of substances deposited by the ancient sea along the shores of the ancient earth—it is supposed that the rivers would bear along trees, plants, and bodies of animals towards the sea, which would throw them back upon its primitive shores, where they would accumulate in beds and masses, and in that condition enter into a state of decomposition and combustion. The mines of coal ought then to be found disposed around the most elevated *nuclei* of the new, or actually existing earth, and which have been the islands of the primeval ocean. Such is, amongst others, the disposition of the mines of coal around the mountains of Hartz, as described by Lehmann [d].

But the simplicity of this theory does not account for the complicated circumstances connected with the position of coal. The numerous beds of sandstone, (*grès*,) of schist, and chalk, which generally separate those of coal [e], shew us that

[d] Desmarets, Nouv. Encyclop. Géog. Phys. art. *Houill*.

[e] Duhamel, Extrait d'un Mémoire, &c. Journal des Mines, viii. 33.

this last substance has been formed at different intervals in a fluid, and perhaps in part, at a period when the present vegetables and animals did not exist. In some places, according to Delamétherie, the intermediate beds which separate the strata of coal, preserve, as well as these strata, a constant parallelism between them. This parallelism is so much the more remarkable, that there are beds of coal, which are scarcely an inch in thickness, although often several leagues in extent. It has been concluded, and with sufficient probability, that these beds were formed in interior lakes, and crystallized in calm waters [f]. It must at the same time be stated, that we observe other beds of coal which indicate circumstances of great confusion. Near Valenciennes, some beds, which are vertical, or almost vertical, are covered over by an alternate superposition with beds parallel to the horizon [g].

Parallelism of the beds of coal.

The great extent of beds of coal presents another subject worthy of consideration; they appear to pass under the very bottom of the sea.

In the Danish island of Bornholm, which is composed of calcareous and schistous earths, of a secondary formation, we find a considerable bed of coal, which comes from the Baltic sea, passes under the island, and extends itself again under the sea, towards the opposite coasts of Scania, a province of Sweden. This bed, the thickness of which is not known, may be from five to seven leagues in length, and more than one league in breadth [h]. We may conclude, according to the apparent direction of the bed, that it ought equally to be extended under the secondary schistous rocks in Scania. Scania runs from south-east to north-west, in the same direction as the bed of submarine coal. In fact, alumin schist (aluminous) is found first at Andrarum, and a bed of coal has been recently discovered

Submarine coals.

[f] Delamétherie, Théorie de la Terre, v. p. 39.

[g] Baillet, inspector of mines, quoted by Haüy, Minéral. iii. 320.

[h] Memoirs of the Society of Rural Economy of Copenhagen, (in Danish,) i. p. 455—496.

at Hoganess, upon the borders of the Sound, or entrance of the Baltic.

Pit coals situated in basalt.

In short, it is a very remarkable thing, that coal, a substance so easily inflammable, is found covered over with substances, which, if they are not the products of volcanos, seem at least to owe their origin to fusion, occasioned by the powerful action of caloric. The most striking example of this collocation of the seams of coal has not yet been examined with due care. The islands of Feroe, which appear to be nothing but masses of basalt, and which rise perpendicularly from the bosom of the sea to the height of 1800 feet, contain an extensive mine of coal, inclining to the variety named "dry coal[i]." It is found in the island of Sudoree, and, according to the descriptions given of it, it seems to have at once, for its roof, its wall, and its support, basalt, trapp, or rocks which are closely connected with these two kinds [k].

All bituminous substances exercise in a singular manner the ingenuity of the naturalist, who, though he can discover the elements of which they are composed, cannot explain the origin.

Jet.

Jet is found so differently described, that we cannot say whether it is fossil wood, or hardened asphaltum. The

Elastic pitch.

elastic bitumen, which occurs in England, near Castleton in Derbyshire, appears, according to the researches of two distinguished naturalists [l], to be a substance identified with the *cahoutchuc*, or elastic gum, which certain trees in Peru furnish. This fossil cahoutchuc transported to so great a distance from the warm climate in which it must have been produced, seems then to furnish a new proof of the astonishing revolutions which our globe has undergone. The state of hardness, however, in which certain portions of this bitumen are found, renders the nature of it very uncertain.

[i] See Charbon.

[k] Mémoires de la Société d'Histoire Naturelle de Copenhague. Voyez, article *Feroe*, ci-apres.

[l] Delametherie, Journal de Physique, xxxi. p. 311; Faujas Saint-Fond, Annale du Muséum d'Histoire Naturelle, I, 261 *seq.*; Mawe, Mineralogy of Derbyshire, viii. 80.

The most celebrated of all the bituminous substances, is assuredly *Succinum*, or yellow amber. We have seen what a prominent part the Succine islands, or the *Electrides*, formed in the history of the ancient geographical traditions, and that we may with equal probability, seek for this country of yellow amber in the Asturias, where that substance abounds in the beds of coal [m]; and in Eastern Prussia, where the Baltic Sea throws pieces of it upon the coasts, and where formerly the fishermen collected lumps of it in their nets [n], whilst now it is the regular working of the hills of sand in the neighbourhood of the sea, which furnishes the greatest quantity [o]. There was lately found at Schlepacken, at the distance of twelve German miles from the sea, the largest piece of amber that was ever known; it weighs 13½ pounds, and is preserved in the royal museum of Berlin [p]. Next to Prussia, Eastern Pomerania furnishes the greatest quantity of amber: where it is also worked in quarries [q]. In general, the whole of the plain which borders the Baltic Sea on the south, produces amber commonly within the beds of sand, and of clay, sometimes in the midst of imperfect coal [r]. These depôts of amber extend from Livonia, and particularly from Courland, to the western coasts of Sleswick, where perhaps the Phœnicians purchased this substance formerly so much sought after [s]. Succinum, or yellow amber.

The situations in which yellow amber occurs; the physical and chemical qualities of this substance, which appears to approach the resinous gums; the insects which are found enclosed within it, as in a crystal prison; every thing, in Origin of yellow amber.

[m] D. Casal, Histoire Médicale des Asturies, dans les Annales des Voyages, viii. 80.

[n] Boet. De Lapid. et Gemmis, l. ii. p. 159. Hartmann, Succini Prussici Historia Physica, etc.; Francfort, 1677, etc.

[o] Hasse, la Prusse, le pays d'ambre jaune et le paradis; Kœnigsberg, 1799.

[p] Kant, Géographie Physique, vii. 154, (supplement.)

[q] Brennus, Journal Littéraire de Berlin, Janvier 1802, p. 13. Téor., p. 141. Ruhs, Mémoires de Poméranie, 1, cah. iv. p. 399.

[r] Seetzen, Magasin minéralog. de M. Hoff, 1. vol., 4e cahier, p. 406.

[s] Heinze, Nouveau Magasin de Kiel, ii. 337 *sqq.* (d'après les Mémoires de l'Académie des Sciences de Copenhague.)

short, connected with its history, would induce us to regard this fossil as a juice which once flowed from a tree, and which, buried in the earth by some natural convulsion, would be impregnated with mineral vapours, and acquire a certain degree of consistency[t]. But as the copal, the only kind of known gum which resembles amber, is brought to us from Africa and the East Indies, it would appear, that the forests in which amber is produced, could not exist in the environs of the Baltic, unless a very elevated temperature prevailed. Thus, these small fragile crystals, which at first seem to be only an object of idle curiosity, become so many monuments of the revolutions which our planet has experienced.

[t] Fourcroy, Élémens d'Histoire Naturelle et de Chimie (édit. de 1789,) iii. 443.

BOOK X.

Continuation of the Theory of Geography. Of the simple substances which compose the solid part of the globe. Section Second: of Metals.

General view of metals.

THE only minerals which remain for us to consider, are metals; substances whose brightness, weight, density, ductility, and fusibility, engage the attention of mineralogists and crystallographers; substances which, forming sometimes the representative signs of the products of industry, and sometimes the useful or the formidable instruments of our arts, and our passions, ought to be carefully noticed in the description of political states; but they peculiarly deserve attention in the details of physical geography, from the intimate relation which they bear to the two great agents of nature, electricity and magnetism. Our knowledge of facts is too limited for enabling us to discuss with advantage the bold hypothesis of some Danish and German naturalists, who pretend to form from analogical conjectures a theory of the electrical and magnetic phenomena observed in metals, and who have even ventured to draw from it the conclusion, that the solid centre of the globe was a metallic mass, all the mineral substances in which were only oxides [a]. This theory, unsatisfactory and defective, notwithstanding of all the attempts to support it by vague analogies, acquires, indeed, some interest, from its approximating to the results of Sir H. Davy's new experiments, which seem to indicate the metallic nature of a number of substances in appearance earthy and alkaline. We must wait the ulterior progress

[a] Steffen, Histoire Intérieure de la Nature. Schelling, Théorie de l'Univers. Id. Journal de Physique Spéculative, i. cah. 2. Ritter, le Siderisme, etc.

of these interesting researches, before we can apply them to explain the theory of the earth. But all philosophers should agree in considering the bearings and position of metals, as a subject worthy our most careful and persevering researches. Physical geography indispensably requires that a subject of this nature should constitute one of its departments; and if we devote to it a certain portion of our pages, our readers will perceive, in the progress of our work, the advantages which are thus afforded us, even in the study of political geography. We shall class metals according to their specific gravity.

Platina.

Platina remained unknown, or neglected, until 1735. Don Ulloa, a Spanish geometrician, who accompanied Condamine and Bouguer, in their voyage, to measure a degree at Peru, having found this metal there, announced the discovery of it in the relation of his voyage. Platina as yet has been found only in the gold mines of America[b], particularly in those of Santa Fé, near Carthagena, in Castille d'Or, and in the mines of Choco, in Peru. It is brought to us in little grains, mixed with gold dust, ferruginous sand, and some particles of mercury. That which has been brought into Europe, contains three or four extraneous minerals[c]. It is the least fusible of all the metals.

To melt it into ingots, it is mixed with arsenic, a substance which renders the platina very fusible, and from which it is afterwards easily separated by roasting. But this process exposes the workmen to vapours, the danger of which is unfortunately too well known. It is of platina that those rods are made, that have been employed in measuring the base of the chain of triangles, whence has been deduced the length of the arc of the meridian which traverses France, and by consequence, the distance from the equator to the northern pole.

Property of Platina.

This metal has been chosen for such purposes, because it is little susceptible of dilating, or contracting from the va-

[b] It is also found in Estramadura in Spain.—T.

[c] Fourcroy et Vauquelin, Annales du Muséum, tome iii. p. 149; tome iv. p. 77. *sqq.*

riations of temperature. Its dilatation, according to Borda, is only $\frac{1}{115000}$ for one degree of the centigrade thermometer, or $\frac{1}{92000}$ for a degree of Reaumur. Whilst a rod of iron dilates $\frac{1}{91730}$ for a centesmial degree, and $\frac{1}{73000}$ for a degree of Reaumur [d].

Gold is only found in its native state, that is to say, almost pure. It exists in all kinds of earth. It is found in little beds in the primitive mountains of gneiss, and of micaceous schist, in the country of Salzbourg, and in Carniola; it occupies veins in the mountains of sienite and porphyry near Kremnitz in Hungary, in the secondary rocks of argillaceous-quartzous schist, or even of sandstone, (*grès*,) at Zalatna in Transylvania, and in an argillaceous free stone, (*grès argileux* [e]) not far from Ekaterinbourg in Siberia; thus, says Werner [f], this metal has been formed in very different periods. It is also proved by the experiments of Sage, Berthollet, Rouelle, Darcet and Deyeux [g], that there are particles of gold existing in vegetables. Berthollet has extracted about 2 grammes, $\frac{14}{100}$, or 40 grains $\frac{1}{10}$ of gold, from 489 hectogrammes, or a quintal of ashes. Werner assures us, that at Zalatna, native gold has been found in half petrified wood, or rather, says he, in bituminous wood [h]. Gold, its position.

The mine of gold which is in Norway is poorer than that in Sweden; those of the north produce altogether scarcely the twentieth part of the quantity furnished by that of Nagyag in Transylvania, or that of Kremnitz in Hungary. But what indeed are all the gold mines of Europe, taken together, in comparison of one single mine in Peru or Brazil? In going from La Paz, towards Potosi, and Tucuman, all the beds of clayey schist are found pene- Geographical situation of gold.

[d] Or about $\frac{1}{32\frac{1}{32}}$, according to the scale of Fahrenheit. One degree of Reaumur being supposed equal to $2\frac{1}{4}$ of Fahrenheit.—T.

[e] *Grès* sometimes means flint or silicious substances, and sometimes is translated free-stone. The context must determine which it designates.—T.

[f] Werner, Nouvelle Théorie des Filons, § 77.

[g] Chaptal, Elémens de Chimie, tom. iii. p. 401.

[h] Théorie des Filons, loc. cit.

trated with veins of auriferous quartz; and the fall of a shelf of rock discovers masses of gold from 2 to 300 pounds in weight [i]. The islands of Borneo, of Celebes, or Macassar, and of Sumatra, situated under the equator, contain very rich mines of gold, though badly worked [k].

Sands producing gold.

Europe has also rivers, which carry along with them some grains of gold; but in Africa, in searching along the rivers, we find almost every where auriferous sand. In Nigritia, the natives are regularly employed every year in this golden harvest, after having finished that of the corn. Near Akim, upon the coast of Guinea, one person may pick up several ounces a day. This increasing abundance of one of the most weighty and dense metals, as we approach the equator, presents to us a question, as interesting as it is difficult to solve.

Quality of gold.

The valuable qualities of gold render it worthy of the rank which opinion has assigned to it amongst metals. Less brilliant than platina, it has a colour more agreeable to the eye. Thus, the poets have not failed to give golden locks to Apollo; to Jupiter a throne of gold; Vulcan employs gold to forge a buckler for Achilles; in short, in the form of an adjective, the words gold and beauty are synonymous amongst the Greeks. Tractable in the hands of art, from its great ductility, gold assumes every form which we wish it to acquire. The goldsmith, the jeweller, the embroiderer, and the gilder, employ it with equal facility. It is capable of the most astonishing superficial extension, thus making up, in some measure, for its scarceness, by its ductility. A quantity of gold, of the weight of one grain (53 milligrammes) can be beaten out into a sheet, the surface of which will cover 50 square inches, or $3\frac{65}{100}$ square decimetres; and when used in the gilding of silver wire, its extension is nearly sixteen times greater. The tenacity of gold is such, says Haüy, that one thread of this metal, of $2\frac{7}{10}$ millimetres, or $\frac{1}{10}$ of an inch

[i] Helm, Journal d'un Voyage de Buenos-Ayres à Lima, (en All.)

[k] Mem. de la Société de Batavia, ii. 166, iv. 589, etc.

in diameter, can support a weight of 244$\frac{6}{10}$ kilogrammes, or 500 pounds, without breaking. As gold is very soft, it must be mixed with copper, when coined into money. This alloy gives it a reddish tinge. Gold acquires a resinous electricity [l].

Native silver is rarely found pure in the bosom of the earth; it is sometimes mixed with copper and iron, and sometimes with gold, but more frequently with arsenic. The same province of South America which possesses the richest gold mines, namely, Peru, contains also great treasures of silver. Silver.

The mines of Potosi produced, from the year 1545 to 1648, about 395,619,000 piastres, but they are exhausted. In North America, Mexico abounds in silver, about 22 millions of piastres being derived from it every year [m]. Silver is apparently diffused throughout the whole extent of the old continent; but the mines which are now best known, are almost all found in the temperate zone of the North. Those of Siberia, of Saxony, and of Hartz, are at the 50th degree of latitude—those of Konigsberg in Norway, at the 60th degree. The produce of these mines, however, is trifling, compared to the mineral riches of America, which are contained within the two parallels, distant thirty degrees from the equator. We are ignorant whether Africa possesses mines of silver equal to those of the New World. Geographical extension of this metal.

Silver is found in quartz, limestone, sulphurated zinc, and sometimes in petrosilex [n]; it is rarely met with in granite rocks. At Frankenberg, in Hesse, leaves of native silver are found adhering to petrifactions [o]. This metal exist in grains (though rarely) in a thread-like form, in thin laminæ, in ramifications, in octahedral crystals, and sometimes in very considerable masses. We are assured, that one was found at Schneeberg, in Saxony, in Its position.

[l] Haüy, Annales du Muséum. iii. 309. *sqq.*

[m] Humboldt, Essai Politique sur la Nouvelle Espagne.

[n] Bergmann, Géographie Physique, i. 266.

[o] Werner, Nouvelle Théorie des Filons, § 78 et 79.

1748, which weighed 400 quintals, or 196 kilogrammes [p]. Another mass was found at Konigsberg, of the weight of 560 marks, (about 270 kilogrammes,) and is preserved in the Royal Museum at Copenhagen. Bergmann says, that there has been found in the sands, upon the coasts of Peru, masses of 150 marks of silver entirely pure.

Quality of silver.

Silver is, next to gold and platina, the most unalterable of the metals---its surface only blackens in those places where there are sulphureous and inflammable vapours. It is remarkable that silver, alloyed with a considerable portion of gold or copper, preserves its white colour; whilst a small quantity of silver or copper, mixed with gold, changes very sensibly the colour of this latter metal. This phenomenon, common to all white metals, made Newton imagine, that the particles of white metals have much more surface than those of yellow metals, and that they are even very opaque; so that they cover the gold and copper, without permitting the colour of these metals to pierce through theirs. They ought, on the other hand, to be more thin, because the white light which they reflect, answers to a greater degree of tenacity, than the yellow of gold of copper [q]. According to the experiments of Brisson, and the calculations of Haüy [r], the specific gravity of a mixture of gold and copper, exceeds the sum of the specific gravities of the two metals when separate about $\frac{1}{11}$. On the contrary, the specific gravity of a mixture of silver and copper, is less than the total of the specific gravities of the two metals, by about $\frac{1}{15}$. Another physical quality of silver is still more worthy of our attention, the property which it has, when dissolved in nitric acid, of crystallizing under a kind of vegetable or arborescent form, producing what is called the tree of Diana. It would seem, that the crystals of which this kind of mineral vegetation is composed, may be considered as small magnetic rods, whose poles, by attracting and repelling each other, determine

[p] Haüy Minéralogie, vol. iii. p. 398. note 2.

[q] Newton, Optice Lucis. lib. ii. part 3. proposit. 7.

[r] Haüy, Minéralogie, tom. iii. p. 389 et 390.

their respective positions [s]. Silver, though less rare than gold, has been preferred to that metal, as a representative of value; the resistances which it opposes to the action of the air and humidity; its brilliant whiteness, and its malleability, render it applicable to a multiplicity of purposes both useful and ornamental, which are too well known to require enumeration.

Sulphuret-ed silver.

Sulphate of silver, that is, silver combined with about $\frac{4}{7}$ of sulphur, commonly bears the absurd name of *(mine d'argent vitreuse)* vitreous silver, though it has not even the exterior appearance of glass. Antimonial sulphureted silver is commonly called red silver, and the fine lively red, which is the essential colour of it, justifies the name. The transparent crystals of this metal form not a bad imitation of the ruby; the more beautiful they are the less silver they contain.

Mercury.

Native mercury is generally found in brilliant and moveable globules, disseminated in the clayey schist, as at Idria in Friuli, or rather in Carniolia; in marl, in quartz, as in the district of Deux Ponts, and in primitive lime-stone, as at Almaden in Spain. This metal requires so little heat for its fusion, that the atmosphere always contains enough to preserve it in the fluid state. The cold of Siberia, however, and of Northern Russia, sometimes converts it into the solid form, which has been erroneously considered as congelation, it is then almost as malleable as tin [t], and admits of being extended into very thin sheets [u]: besides, its oxide repasses to a metallic state, without the intervention of any foreign substance. It possesses, then, the essential qualities of metals, and approaches the nature of those that are the most perfect. Mercury amalgamates with almost all metallic substances, but chiefly with gold, silver, tin, and bismuth [x]; it is this property, joined to the facility

Its congelation.

[s] Ritter, Mémoires sur le Galvanisme, i. cah. 2. p. 280.

[t] Bergmann, Géog. Phys. i. 227. Comp. Hachette et Hassenfratz, dans le Journal de l'Ecole Polytechnique, i. cah. p. 123. et suiv.

[u] Braun. Comment. Petrop. novi. xi. p. 268. Blagden, Philosoph. Transact. 1783. vol. lxxiii. p. 329.

[x] Gellert. Principes de Chimie Docimastique, 152, (en All.)

with which it evaporates, that causes it to be employed in gilding, and in working mines of gold and silver. The silvering of glass is effected by amalgam of mercury and tin. Philosophers make use of the same amalgam to spread upon the rubbers of electric machines. The efficacy of medicines formed of oxides of mercury, is entirely owing to the facility with which these oxides are decomposed by parting with their oxygen. All these physical and chemical qualities shew what an important part mercury would act in the formation of our earth, if it there existed in great quantities. At present, this metal is found only in very small portions, and at great distances—it seems to fail in countries in the vicinity of the arctic pole. The whole of Siberia presents to us only two or three ambiguous specimens [y]. The New Continent is not more abundantly provided with it. The natural amalgam of mercury and silver, is called silvery mercury. It remains for us only to notice the sulphuret of mercury, well known under the name of cinnabar, or vermilion cinnabar, and which is sometimes found in regular veins.

Geographical situation of mercury.

Cinnabar.

Lead.

An ignoble metal claims the rank next to mercury, that is, lead, a substance of very dense structure, but extremely deficient in point of hardness, elasticity, and even ductility. It is, however, of great utility in its metallic state; conduit pipes, balls for guns, and other plain and coarse implements are made of it; and the oxides of lead are employed in many of the arts. It is lead which gives to glass an unctuosity which renders it susceptible of being easily cut and polished. It is to lead, or to its red oxide, that glass, called flint glass, owes the quality which renders it so valuable for the construction of the object glasses of achromatic telescopes,—the quality of divesting the images of those colours, with which they appear to be edged when we view them through a common telescope. The oxides of lead furnish a variety of colours both to the pallet of the painter, and the toilet of the modern Laïs.

[y] Georgi, Description de la Russie, iii. 406.

This metal is generally found mineralized by sulphur, forming an ore commonly called galêna, which is almost always mixed with iron, with antimony, and especially with silver. This ore is generally worked only for the purpose of extracting from it the silver it contains. Werner specifies seventeen formations of galena of different periods, in all sorts of rocks, from the quartz to pit-coal [z]. There are no kind of mines more common in Europe. The kind of galena which contains silver, is met with in Danish Laponia. But lead is not found in abundance, any where in the North of Europe, or Asia. It begins to discover itself in great quantities, only in Germany, France and England. We are assured that in the interior of Louisiana, it forms vast beds upon the surface [a]. Carbonate of lead, or mineral white lead, often accompanies galêna; it is an oxide mineralized by carbonic acid. Molybdate of lead, or the oxide mineralized by molybdic acid, is found at Bleyberg in Carinthia; it generally bears the name of yellow lead. The red lead of Berezof in Siberia is mineralized by the chromic acid. It is still doubtful whether there exists any lead in the native state.

Position of lead.

Geographical extension.

Nickel is not a very ductile metal; it is of no use in the arts, but it possesses some magnetic properties [b]. It generally accompanies cobalt, an equally magnetic substance; these two metals, of a nature nearly allied to that of iron, and often containing particles of it, seem to occur most plentifully in the north.

Nickel.

Copper, one of the metals of which nature is most lavish, appears to occupy two great regions of the globe which admit of being distinctly defined. We know that it abounds in Norway, in Sweden, in Hungary, in England, in the Uralian mountains, throughout all Siberia, in Chinese Tartary, and Japan. We must also add, that several islands between Kamstchatka and America produce masses of native cop-

Copper; its geographical extension.

[z] Werner, Théorie des Filons, p. 156-161 (en All.)

[a] See Description de la Louisiane.

[b] Expériences des Biot, cité dans le Tableaux des Espèces Minéral de Lucas, p. 297. Comp. Haüy, Minérals, iii. 512.

per[c]; that immense beds of it are found upon the banks of the Ohio[d]; and lastly, that there have been signs of its existence in Greenland, and in Iceland[e]. This metal then seems to be common to all the countries situated in a zone of about 45 degrees of latitude around the northern pole. But it is found on the other side, over all the south of Africa, from Congo[f], to the Cape of Good Hope[g], and according to Beniouski in Madagascar. The southern extremity of America appears also to contain considerable mines of it[h]; and Brazil presents to our notice, an immense block of it in the native state. It appears then, that this mineral is accumulated at the two extremities of the two great continents. We must at the same time admit, that this interesting sketch may meet with objections, drawn from the existence of extensive mines of copper in the country of Morocco[i]; in the island of Cyprus, and Turkish Armenia, mines which by connecting together the two regions that have just been pointed out, compel us to regard copper as a substance common to all the zones of our planet.

Position of copper.

With respect to native copper, naturalists agree in distinguishing two different formations; copper of the first formation is in crystals, in thin plates, in threads, in clusters, which are commonly found attached to quartz, or schist, and sometimes primitive limestone, as is the case near Ekaterinbourg in Siberia, and at Tunaberg in Sweden.

The copper of cementation is of more recent formation; it is obtained from sulphate of copper, (commonly called

[c] Georgi, Russie, 424. Sauer. etc.

[d] Michaux, Voyages aux états de l'Ouest.

[e] In almost all his descriptions of mines either of metals or coals, M. Malte-Brun seems to forget there is such a country as England, remarkable for its mines of tin, lead, iron, copper, and coals. At the time when he wrote, it was the fashion, if possible, to forget it.—T.

[f] Lopez. Relazione di Congo, p. 14. Cavazzi. trad. de Labat. i. 35.

[g] Sparmann, Voyage, 596. (en All.) Patterson, Barrow. etc. etc.

[h] Vidaure, Istoria Geografica di Chili.

[i] Hœst, Notices de Maroc. (trad. du Dan. en All.) p. 310. Chenier. etc.

vitriol,) held in solution in water, and decomposed by the application of heat. It forms concretions upon different stony substances, and even upon organic bodies. Waters impregnated with particles of copper, are called cementatory waters. Amongst the ores of copper, the most common is the pyrites of copper. In the mines of Kopparberg in Sweden, of Rœras in Norway, in those of Siberia, and in general in all the great copper works, this metal is principally obtained from pyrites of a yellow or iris colour, in which it is found mineralized by iron and sulphur. The grey-coloured copper contains silver, antimony, lead, sulphur, &c. The sulphuret of copper, or copper combined principally with sulphur, has a vitreous appearance. In the state of oxide, copper assumes various tints, red, blue, or green. The silky or pearly carbonate of copper, (the satin-like ore of Bergmann,) presents a green colour like an emerald, softened by a sort of satin lustre, which has the effect of giving it a more beautiful appearance. This same copper, in a state of concretion, forms the substance named malachite, which is susceptible of a fine polish, and of which the cheeks of chimneys, snuff boxes, and various trinkets are made. It is, to use the happy expression of M. Haüy, the alabaster of metallic substances [k].

Cementatory waters.

Malachite.

As it is the province of political geography to treat of manufactories which have the working of metals for their object, we shall be pardoned, we trust, if we mention in a few words the eminently useful qualities of copper. This mineral, while it is much more ductile than iron, is also more durable than tin and lead. Its tenacity is such, that one wire of copper of 2,7 millimetres, or $\frac{1}{10}$ of an inch diameter, can sustain without breaking, a weight of 146 kilograms, or about 320 pounds English. The useful qualities of copper are partly balanced by its very changeable nature. Exposed to the air, or to damp, it is very soon covered with that rust known under the name of verdigris, which is one of the most active poisons: When melted and

Qualities of copper.

[k] Haüy, Minéralogie, iii. 575.

refined, it is called purified or rose copper, which is less dense than native copper. What we call yellow copper, or brass, is a compound of copper and zinc, which is obtained by the cementation of copper with calamine [l], and which, from being less subject to rust, furnishes the watchmaker, the mechanical philosopher, and the geometrician, with so many instruments of general use, exquisitely delicate in their workmanship, and at the same time of great durability. But if the two metals are directly united by fusion, the mixture takes the names of pinchbeck, tombac, and gold of Manheim. The brass dilates $\frac{1}{1000}$, for every degree of Reaumur, and $\frac{1}{1800}$, for every degree of the centigrade thermometer [m]. The specific gravity of brass is about $\frac{1}{10}$ more than the sum of the two specific gravities of copper and zinc.

Bronze. Bronze is made by uniting a certain quantity of tin with copper; it is more elastic and sonorous than pure copper. It is this compound, that is to say, the perverted use of it, which, following the steps of the conqueror, hurls forth the thunderbolts of war against peaceful nations. It was of bronze that the genius of the Greeks fashioned the august images of their gods, and the cherished features of the benefactors of the earth. Without the aid of copper and iron, man could neither have attained his present height of civilization, nor have lent to crime the destroying energy of the infernal powers. But let us return to the subject immediately before us.

Cobalt. Cobalt, which partakes with oxidated iron a magnetic property in an eminent degree, seems to be of two formations of different ages. The white cobalt of Werner, (or grey cobalt of Haüy,) is frequently found in veins in the secondary mountains of Hesse and Thuringia. The arsenical cobalt of Haüy, which Werner calls shining cobalt, exists only in the primitive rocks, and is accompanied by quartz and primitive lime-stone. This mineral is employ-

[l] Calamine is the ore which furnishes zinc in greatest abundance.—T.

[m] Borda, cité par Haüy, ibid. p. 526.

ed to make a fine blue glass, named smalt, which, in a pulverized state, is known under the name of Saxon blue[n].

Tin is of a formation, which, according to a celebrated mineralogist, carries us back to one of the remotest periods in the history of the globe; it has never been found in secondary mountains; it exists, however, he says, in all porphyries. The singular manner in which tin mines are distributed upon the surface of the globe, appears to us to be extremely remarkable. This metal is found in Cornwall in England, in Saxony, in Bohemia; it is scarcely ever met with in other parts of Europe; it entirely disappears when we penetrate into the interior of the ancient continent, and does not again discover itself till we reach the peninsula of India, on this side of the Ganges[o], whence its mines extend to the peninsula of Malacca, and to the islands of Sumatra, Banca, and Japan. Africa and South America produce but little of it. The tin which is used in the arts for coating glass, for solder, for farming utensils, and for the composition of scarlet, possesses the singular property of rendering more hard, and more sonorous the metals with which it is mixed, although by itself it is deficient in these two qualities. At the same time, it takes away ductility from metals possessing that quality in a high degree, while it does not diminish the ductility of the less ductile metals[p]. Tin. Geographical situation. Qualities.

Iron is profusely distributed throughout nature. It enters either as a colouring or a combining principle into a great number of mineral substances; it is a stranger neither to vegetables, whose tints it enlivens, nor to animals, upon whom it exerts a salutary influence. As an insulated substance, it is found in almost every part of the ancient continent; it is however, more common, or, at least, accessible to our researches in the north temperate zone, particularly towards the northern part of it. Iron.

[n] Werner, Théorie des Filons, ch. vii. § 76.

[o] Wahl, Ostindien, ii. 746. (en All.)

[p] Rinmann, History of Iron, § 146, p. 493. (in German.) Bergmann, Opusc. Phys. ii. 471.

Geographical extent of iron.

What an immense quantity of iron is contained in the mountains of Scandinavia alone! The mountain of Taberg, to the south of Sweden, presents only one entire mass of this mineral. The north of Asia equally abounds in iron; the imperfect accounts which we have received of Canada, and the northern parts of the United States, inform us that these regions are provided with excellent iron, though copper appears to predominate there. Southern Africa, it would seem, abounds still more in iron, than the places just mentioned do in copper [q]. No kind of rock or earth is a stranger to it. It is found in granite in detached masses, in schist, in a thread-like form, in the free-stone in beds; it exists in mud, and turf.

Native iron.

The great masses of native iron, found in Siberia by Pallas [r], and in America by Rubin de Cilis [s], have been for a long time considered by most naturalists as productions of art, or of volcanic agents. Wallerius, in stating that native iron is found upon the borders of Senegal, has merely copied from ancient travellers, whose narratives want precision. But, it is an undoubted fact, that the substances found at Kamsdorf in Saxony [t], and at Oulle in Dauphiny [u], are actually natural productions; and why cannot nature present to us iron in its pure state, since it offers it to us under the form of very hard and compact steel [x]? The most ancient iron ore, according to Werner, is that of magnetic iron, which Haüy calls oxidulated iron; it is to a variety of this ore that the name of loadstone has been given.

We shall speak elsewhere of the phenomena which this substance presents. The grey or specular ore of iron, (the oligiste iron of Haüy,) abounds in Sweden, in Norway, in

[q] Cavazzi, i. 83. Thomann, 113.

[r] Bergmann, Sciagraphia, Edit. de Delamétherie, ii. 153. Romé de l'Isle, Cristallog. iii. 167.

[s] Annales de Chimie, v. p. 149.

[t] Brochant, Minéralogie, ii. 217.

[u] Schreiber, Journal de Physique, xii. p. 3. *sqq.*

[x] Godon Saint-Menin, Journal de Physique, lx. 310. *sqq.*

the Island of Elba, at Framont in Les Vosges; it is the most easy to work of all the ores of iron. Sparry iron ore is only a carbonate of lime, more or less mixed with iron; the lime with which the ore is combined facilitates the fusion. The iron which is drawn from it is of an excellent quality, and it has a very great tendency to pass into steel, even in the first fusion: this is what is called steel ore [y]. A kind very generally distributed, and commonly worked, is that of oxidated iron, which comprehends, amongst others, the hematites, the ochres, the martial géodes, and particularly the iron in globules, similar to peas or eggs. The metal obtained from oxide of iron in globular masses, sometimes contains a certain quantity of phosphoric acid, which renders it brittle and inductile; this is what the French call *fer cassant à froid*, and we, cold short iron.

Sulphuret of iron, which is commonly named martial or ferruginous pyrites, is one of the most remarkable substances which enter into the composition of the globe. It is very extensively distributed, being found in quartz, in marl, in the argillaceous schist which lies upon coal, and it is even mixed with coal itself. In the greatest depths to which man has ever been able to penetrate in the most considerable mines, we continue to observe the ferruginous pyrites, until our progress is arrested by the subterraneous waters [z]. There is auriferous pyrites, which although chiefly consisting of decomposed sulphuret of iron, is worked like ore of gold, and with the view of extracting from it this last metal: Such is the method employed in the gold mines of Berezof in Siberia, of Adelfors in Sweden, and others. The origin of hæmatites, and ferruginous ochres, is owing, according to the opinion of the majority of naturalists, to the decomposition of sulphureted iron, the remains of which the running waters have carried along with them; hence they are called transported minerals, in order to distinguish them from other minerals which seem to have been formed in th

Sulphuret of iron, ferruginous pyrites.

[y] Haüy, ii. 180. et suiv. p. iv. 117 et 118.
[z] Henkel, Pyritologie, trad. Franc. p. 97.

spot where they are found. These transported ores then are of recent formation, compared with the others, and one can easily suppose that they are formed every day.

Vitriol of iron. Vitriol of iron is nothing else than the sulphate of iron, which is generally procured from the decomposition of sulphureted iron. Sulphate of iron, or vitriol, is of great service in dyeing, it is used as the principle of black colour, from the property which gall nuts and other astringent vegetables possess, of precipitating iron contained in the vitriol under the form of black particles of extreme fineness.

Emery. Emery is an oxide of iron, intimately united with the basis of alum, and with silex. This substance is valuable in the arts, on account of its great hardness. By bruising it in steel mills, it is reduced to a powder, whose sharp and hard particles can, by the application of friction, give a polish to all existing substances, except the diamond. "Iron," says M. Haüy [a], "such as nature produces it, is very different from that whose appearance and use are so familiar to us. It is nothing but an earthy mass, a dirty and impure rust; and even when iron presents itself to us in the mine with metallic brightness, it is still very far from possessing the qualities required for the multiplicity of uses to which it can be applied. While man need only purify gold, he must, if the expression be allowed, create iron." This metal is generally susceptible of three different states. What is called cast or pig iron, is the metal after its first fusion, deprived of a more or less considerable portion of its oxygen, and combined with a part of the carbon with which it came in contact in the casting furnace. Cast iron is not yet rendered malleable; for it is peculiar to iron, that of the two properties of fusibility, and ductility under the hammer, it can possess the one only at the expense of the other. To render iron ductile, it is again submitted to the action of a furnace, the elevated temperature of which determines, by a new exertion of affinities, the oxygen remaining in the cast iron to combine

[a] Haüy, Mineral. iv. 2.

with the carbon, which had been incorporated with the iron, and thus to form carbonic acid, which constantly disengages itself from the mass. Iron, after this process, is found in the greatest state of purity to which art can bring it: It is then exposed to the action of a large hammer, whose redoubled strokes, by bringing the metallic particles into closer contact, unite them more perfectly together, and render the iron ductile. It is then called forged iron. In this new state it is no longer fusible; and the most violent heat of our furnaces can at most only soften it, and convert it into a kind of paste. Forged iron placed in contact with carbonaceous substances, and again softened by the action of the fire, the moment it enters into combination with these substances, or rather with the carbon which they contain, is converted into steel.

The operation of tempering which steel undergoes does not change its nature, it only varies the arrangement and aggregation of its particles: it augments at once its hardness, its brittleness, and its volume, and gives it a coarser grain than that of steel not tempered [b]. Thus the difference between cast iron, forged iron, and steel, depends on two principles, namely, oxygen and carbon: their union constitutes cast iron; the absence of both, at least in a perceptible quantity, characterizes forged iron; and, in steel, carbon exists alone without oxygen. Steel.

We shall say nothing of the use of iron in its three states; it is universally known. We shall only observe, that the tenacity of iron is such, that this metal reduced into a wire of about 2.7 millimetres, or $\frac{1}{10}$ of an inch thickness, can support without breaking a weight of 210.3 kilogrammes, or 450 French pounds. Iron is very oxidable, and it exerts a very strong elective affinity to sulphur. United with silex and alumina, it imparts an extreme hardness to the rocks which contain it. Thus, there is no metal which allows itself to be so easily decomposed, and no metal forms a more unalter- Qualities of iron.

[b] Vandermonde, Monge et Berthollet, Memoirs de l'Académie des Sciences. 1781.

able cement. Its magnetic virtue readily communicates itself to the other metals with which it is mixed; $\frac{4}{100}$ of iron makes copper magnetic, $\frac{5}{100}$ have the same effect upon tin [c]. These physical qualities prove what an important part it must have acted in the formation of those aggregate substances which compose our globe.

Zinc. Zinc, which forms the connecting link between the ductile metals, and those which are not so, is found oxidated, and then it is commonly called calamine, or lapis calminaris. There are mines of it in Alsace, in Normandy, near Aix la Chapelle, in Brisgaw, in Carinthia, in the county of Somerset in England, and many other places. Calamine, according to Werner, is not found in the primitive rocks. It oftener occurs sulphureted, and then the vulgar name of it is Pseudo-galena, or blende. This mineral is scattered over Sweden, Norway, Saxony, and Bohemia, and we may say almost every where. It generally accompanies galena, or sulphuret of lead. It is often mixed with iron, gold, and silver. The sulphate of zinc, which is rarely a product of nature, is called white vitriol, or white copperas. The metal that is brought from India, under the name of tutenag, is, according to Bergmann [d], zinc in a state of purity. If the air be admitted to zinc when brought almost to a white, the metal burns with a splendour which nothing can equal, and which is too dazzling for the eye to support [e]. This property serves to characterize zinc not only amongst the metals, but even amongst all combustible minerals.

Bismuth. Bismuth, from its great fusibility, is used for various metals; it is found, according to Werner, only in the primitive mountains; it occurs, however, attached to jasper. Of all the minerals easily oxidable, it is the only one which is found more frequently in a metallic form, than in that of an ore properly so called [f].

[c] Rinmann, Histoire du Fer, i. p. 146. (en All.)
[d] Bergmann, Géog. Phys. i. 233.
[e] Macquer, Dictionnaire de Chimie.
[f] Brongniart, ii. 131.

Manganese very often accompanies mines of iron, particularly in the secondary mountains; it is a colouring principle very extensively distributed in nature; and it is that which gives a violet hue to the crystals of fluate of lime, and to a number of the schorls. Mixed in a small quantity with the substance of white glass, it has the property of clarifying it, and of freeing it from false colours. Manganese.

Antimony, once celebrated in the laboratories of the alchymists, who hoped to discover in it the philosopher's stone, is now employed with success in the composition of various medicines, in the casting of types for printing, and as an alloy with tin, to form what is named prince's metal. It is found native in quartz and primitive lime-stone; sulphureted or grey in the secondary mountains, and often also united with galena. Capillary antimony often contains silver, and has been called plumose silvery antimonial ore. The crystallization of fused antimony, presents a stellular and foliated appearance [g]. Antimony.

Scheelin was, until very lately, called by the Swedish name Tungstene. It is a very weighty mineral, obtained from a ferruginous striated substance, known under the German name of Wolfram. It is principally found in the primitive mountains, and often accompanies tin. Scheelin.

Uranium is a metal lately discovered, and comprehends the varieties once called horned copper (cuivre corné,) and peck-blende. It is, acording to Werner, of ancient formation. Uranium.

Tellurium, another metal recently observed, is found chiefly in the auriferous mine of Nagyag in Transylvania, which gives from 45 to 170 ounces of silver to the quintal, and from 200 to 210 deniers of gold to the marc. Tellurium is attached to quartz and manganese; it is still very rare. Tellurium;

Molybdenum appears to be of ancient formation—small masses of it are found in granite, in several places of Sweden, Norway, Saxony, and Bohemia [h]. Molybdenum.

[g] Haüy, iv. 259.

[h] Steffens, l. c. 158.

Arsenic. Arsenic, the name of which alone excites an emotion of terror, is not often found by itself; but it serves to mineralize a great number of metals: rubbed or warmed, it discovers itself by the smell of garlic, which it emits. In its native metallic state, it is of a steel-grey colour. It is the oxide of arsenic, under the form of a white powder, which constitutes one of the most violent poisons. That which is met with around volcanoes, is mineralized by the sulphur.

Titanium. Titanium, another metal of modern discovery, is found in a state of red oxide, under the form of a ferruginous stone, and united with silex and lime. Of all the new minerals, it is the one which is most interesting to physical geography: it seems to occupy the same place in relation to iron in the primordial mountains, that manganese holds in those of secondary formation. All the iron which is found in the primitive trapp of Norway, particularly near Arendal, is more or less combined with titanium [1].

Chrome, Tantalium, Cerium. Chrome, which colours the emerald; tantalium, which is insoluble in acids; cerium, discovered like the preceding, by Swedish philosophers; columbium, procured from the United States, &c.; and three or four metals which are found combined with platina, have not yet acquired importance enough to claim our attention. The multiplicity, however, of the substances which chemistry has discovered, should inspire us with a salutary distrust of systems which tend to establish general analogies between bodies, of the very number, not to say the properties, of which, our knowledge is as yet so vague and imperfect.

[1] Steffens, l. c. 158.

BOOK XI.

Continuation of the Theory of Geography. Of Aggregate Substances which compose the Solid part of the Globe. First Part: Of Rocks and Earths, and Volcanic Productions.

We have already considered the simple substances which enter into the composition of our globe; and in surveying them, we have been constantly on our guard against the influence of systems, which pretend to determine the period and manner of the formation of these substances. This was not an arduous task: we had only to follow, though with very different views, the track already marked out by the father of modern mineralogy. A more intricate path now lies before us: We come now to the consideration of the *masses* formed by the aggregation of several simple substances, which constitute either rocks or earths, according as they are found in a state of hardness or softness. There the most enlightened guides differ; and instead of shewing us the way, they have to seek for it themselves, amidst the confusion and obscurity arising from the introduction of *general terms*, before *general ideas* had been accurately fixed.

Classifications of rocks.

The classification of rocks, founded solely upon the chemical and geometrical characters of the simple substances of which they are composed, overlooks the intermixture and relative position of these masses, that is to say, the two characters under which physical geography ought chiefly to consider them. On the other hand, geological classification, though formed more in reference to these two points of view, are infected by one capital error, since their char-

acteristic distinctions are derived from the *origin* of rocks. This is unquestionably taking for granted the very point to be proved. To facilitate such a method of systematizing, facts are assumed, the demonstration of which ought to form the boundary of the science. Accordingly, the different aspects under which these facts have been viewed, have given rise to as many different forms of phraseology, as there have been celebrated geologists. Basalt, for example, ranged by some among the *trapps*, a species resembling the primitive rocks, is placed by others at the head of lavas, or substances ejected by volcanos. In the present day especially, when the observations of Werner and Cuvier, compared with the discoveries of Davy and the experiments of Hall, have given us a glimpse of a theory of the earth, much more scientific and more comprehensive than the unwieldy systems of the Neptunists and Vulcanists, it is an indispensable prerequisite to a methodical description of aggregate substances, to discover some principle independent of any system that has been founded on opinions entertained as to the origin of these subtances. This principle appears to be found in considering these substances as to the *mode of their aggregation*, provided that we confine ourselves to the formation of extensive classes, and do not require more narrow limits than those which actually exist in nature. It would seem that nature has placed at wide distances land-marks, which serve to direct our course; but that in the intervals between these land-marks, she has left to our choice a variety of paths, all of them equally good. According to this principle, we think that physical geography should classify aggregate substances in the following manner;

Principle of classification.

A. AGGREGATE SUBSTANCES, *properly so called*, (united according to general laws, chemical or physical.)

1. *Crystallized Rocks*, or such as indicate a crystallized texture. (Granite, primitive schist, primitive calcareous porphyry.)
2. *Conglobated Rocks*, or such as present an union of fragments of crystallized rocks, conglutinated by a crystallized cement. (Primitive pudding stones, amygdaloids.)

3. *Stratified Rocks,* or such as exhibit a contexture similar to that of a sediment, which had deposited itself in layers. (Limestone composed of shells, free-stone, (*grès,*) jasper, &c.)

N. B. Stratified substances in their state of softness, are called *stratified earths.* (Clay, marl, &c.)

4. *Conglomerated Rocks,* or such as present a mixture of fragments of crystallized and stratified rocks, united by a stratified cement. (Variegated marbles and secondary pudding-stones.)

5. *Coagulated Rocks,* or those presenting the appearance of melted matter, which had been coagulated or congealed. (Basalts of Werner, compact lava, lithoïdes lava of Dolomieu, Haüy, Faujas, &c.)

B. Associated Substances, (united according to mechanical laws, or according to chemical or physical laws, special and accidental.)

6. *Earthy Accumulations,* or rocks and earths which exhibit only an association purely mechanical, of parts accumulated one upon another. (Calcareous tufa, &c. coloured marbles, united by a cement of tufa, clay deposited by water, and otherwise, *(argile d'alluvion et de transport,)* peat, &c.)

7. *Volcanic Productions,* or substances thrown out by volcanic fire, through the openings and crevices of the solid surface of the globe. (Vitreous lavas, volcanic cinders, scoriæ, pumice stones.)

8. *Bolides,* or masses precipitated from the atmosphere.

C. Substances Intercalary or Adventitious, (those which are foreign to the aggregations and associations of mineral substances.)

9. *Remains of Organic Bodies,* vegetables and animals; (*a*) petrifactions; (*b*) impressions; (*c*) remains in a natural state.

Let us rapidly survey the vast laboratory where nature works these wonderful combinations, of which we have been pointing out the most striking and accessible.

Crystallized rocks appear to have been formed by the simultaneous crystallization of several simple substances in a state of chemical solution, and united, according to their affinities, so as to form an homogeneous whole. They have a granulated texture, which loses itself in the dull clammy or compact texture, on the one side, and in the lamellated, on the other. Crystallized rocks.

The rocks which occupy the summit of the scale of crys-

tallization, are incontestably those which have for their base, quartz, mica, and feldspar, and are distinguished by
Granite. the name of *granite*. Sometimes a fourth substance, *amphibole*, called also primitive trapp, or greenstone, is mixed with it, or replaces the mica, or the quartz. Granite has even been found mixed with a little lime; but it is always siliceous substances, especially feldspar, which predominate in its composition. The agreeable variety of colours which the feldspar reflects, the lustre of the mica, the whiteness of the quartz, the sombre green of the amphibole, often impart to granite the most magnificent appearance, especially when polishing has developed their natural shades; thus the eye contemplates with delight the *rose-granite* of Egypt, composed of feldspar and mica[a]; the *antique basalt*, or black granite, in which the amphibole conceals the
Varieties of granite. transparent laminæ of the feldspar[b]; the *orbicular granite* of Corn, formed by a singular species of crystallization, which has united in one mass of white feldspar, and of amphibole of a blackish green, distinct balls of the same substance[c]; lastly, the *graphic granite* of Siberia and Scotland, the elements of which, disposed in broken lines, suggest the idea of Hebrew or Runic characters[d]. *Granite* appears to be the most ancient of the rocks, and to constitute the base of the primitive earth. It is not improbable, that it forms an immense vault around the globe; we know, at least, that granite is every where found beneath all the other rocks, and that of the highest mountains in the principal chains of the world, it is granite which constitutes the foundations and the mass. The crystallization, which has united the substances of granite, must have occasionally met with one or other of them in excess; it has accordingly formed *feldspar*, *micaceous*, and
Quartzeous rocks. *quartzeous* rocks. These are rarely found pure. There appears, however, to have been a very peculiar formation

[a] Dolomieu, Journal de Physique, Ventose, an ii. tome i. p. 196.
[b] Id. ibid. Septembre 1792, p. 3.
[c] Faujas Saint-Fond, Essais de Géologie, ii. 182.
[d] Patrin. Hist. Natur. des Mines. i. 101, Faujas, l. c.

of pure quartz; strong veins of it are seen traversing even the granite mountains, and the vast wall of quartz upon the mountain of Felsberg, near Manheim, excites the wonder of the naturalist[e]. But to the admiration of these phenomena succeeds the spirit of disputes, classifications, and nomenclatures. It is often impossible to discover the facts in the midst of the geological discussion to which they have given rise. The rock which most nearly resembles the granite, unites to the granulated structure of the latter an arrangement of parts, which gives it a foliated appearance; the quartz and feldspar are found there in grains, but the mica forms bands, or very thin layers, in which the two other substances are contained. This is the *micaceous rock* of Haüy, the *gneiss* of Werner, and the foliated rock of Saussure[f]; but frequently talc, or even argil, supplies the place of mica in these foliated rocks, a circumstance occasioning continual mistakes. There are some mineralogists who give to the name of *gneiss*, an extension which renders all definition impossible. Micaceous rock. Gneiss.

The *micaceous schists* are rocks which occur in great laminæ, composed of quartz and mica. It appears that they recede by imperceptible gradations from the granulated texture of granites, and that they become more and more mixed with alumina or argillaceous earth, an earth, the presence of which seems to prevent crystallization from taking place. Micaceous schists.

The *argillaceous schists*, in which alumina or argillaceous earth predominates over the silex, occurs in the form of large unbroken laminæ; a circumstance which constitutes what we call the *schistcous structure*. These imperceptible transitions from one kind of aggregation to another, render all classifications uncertain. No one has yet been able precisely to determine the four or five kinds of rocks, to which the names of *horny schists* and of *wacke*[g] Argillaceous schists. Horny schists.

[e] Faujas, l. c. p. 94.

[f] Saussure, Voyages, § 1359, 1679, &c. Haüy Minéralogie, iv. 432.

[g] Comp. Delaméthorie, Théorie de la Terre, ii. p. 337—380. Werner, cité par Saussure, Voyages, § 1301.

are given; they are merely combinations of silex and alumina, with a little lime and iron. The horny texture is found in part in certain rocks, composed as it were of a paste, in which masses of a more perfect crystallization are imbedded. These are the *porphyries*, rocks which baffle more than any other kind the zeal of classifiers [h]. Sometimes it is the paste which is not homogenous, and sometimes the imbedded crystals which constitute the species or the variety. The porphyries, properly so called, are masses of imbedded felspar, coloured by a metallic oxide, and containing crystals of the same kind. Such is the superb *red antique porphyry*, originally from Egypt, and of which only imperfect varieties are to be found in Europe. Such is still the *ophites*, or *serpentine antique porphyry*, although chequered with plates of amphibole; a substance which abounds more and more in black porphyries. All the real porphyries commonly found in the vicinity of granite, are distinguished from it only by that pasty substance which serves as their base; but they differ also from *pudding stones*, or conglobated rocks, by the perfect crystallization of this paste or cement [i]. One may easily conceive how difficult it is to fix the innumerable shades which occur in the crystallization of these rocks; it is this which has led geologists to create a class of *porphyroidal rocks*. The disorder, or rather the capricious order, according to which the particles of these rocks have crystallized, sometimes occasions the most brilliant and fanciful appearances. Who would not admire the *orbicular porphyry* of Corsica [k], which, on being polished, displays circles composed of little yellowish red leaves, arranged in rays around a reddish brown kernel, and which presents to the eye a transverse section of some unknown and delicious fruit?

Porphyry.

Porphyroidal rocks.

Trapp [l] is composed nearly of the same substances as

Trapp.

[h] Comp. Haüy, iv. 435. Faujas St.-Fond, Essai, ii. 405, &c.

[i] Saussure, Voyages, § 149, *sqq.*

[k] Faujas St.-Fond, Essais de Géologie, ii. 245, and planche xx. bis.

[l] A name derived from the Swedish *trapp*, a stair or ladder. Saxum trapeaium, Waller, sp. 220.

porphyry. They are united in the same proportions, only the iron abounds more in trapp; but this arrangement in small grains, united sometimes by a cement, does not present the shining crystallization of granite and porphyry [m]. Trapp rocks have a tendency to separate and subdivide into rhomboidal fragments, resembling the steps of a staircase, which often gives them the appearance of rocks called *basalt*, by the moderns. The celebrated Werner, indeed, considers these two kinds of rocks as the same, and comprehends them under the name of *primitive trapp*; an opinion which, at present, seems to be received only in the school of that mineralogist.

The rocks of *petrosilex* and of *jade*, as well as that composed of amphibole and mica, which Werner names *grunstein*, that is, greenstone, forms small varieties, resembling trapps and porphyries in their relative positions, although the amphibole rock, amongst others, often has the crystallized texture of granite. Of all the elementary earths, the calcareous, and, next to it the magnesian, have the least contributed to form crystallized rocks. Petrosilex, jade, &c.

The *primitive limestone*, or that in which there is not a vestige of animal remains, is not very extensively distributed; it is rarely found amongst the foliated granites, and the micaceous schists; the calcareous banks, in the argillaceous schists, have a texture less perfectly granulated, and present a compact or lamellated fracture [n]. It is amongst the stratified rocks that chalk shews itself in abundance; it is at the head of these aggregations, as granite is at the head of rocks purely crystallized. Primitive limestone.

Magnesian earth appears to predominate in the *talc* rocks, whether compact or schistous, in the *serpentine*, the *ollair* or *potstone*, *steatites*, or soap rocks, and some other aggregations, which, in truth, often occur in the primordial mountains; but which form in general only small subordinate masses. There are rocks of serpentine, however, Magnesian rocks.

[m] Saussure, Voyages, § 145.

[n] Werner, cité par Steffens, l. c, 21.

which rise to a very great height[o]. May we not imagine that the alcaline particles, existing in feldspar, one of the elements of granite, may be separated from it to form a series of insulated rocks? It is at least very remarkable, that magnesian earth seems in a manner to arrest the progress of pure crystallization, and to disappear with the primordial rocks, not to shew itself again either in stratified mountains, or in accumulations, but only in the waters of the ocean. We ought to pause a little to consider these crystallized aggregations, which seem to have preceded the birth of our mountains, of which they form the most solid part. We leave, however, to the naturalists by profession, the task of classifying the innumerable modifications of aggregate substances, which we have named *conglobated rocks*. We may conceive, that the circuit of the globe, scarcely consolidated in the bosom of primitive chaos, must soon after its formation have begun to waste away. The action of different elements, probably the rapid alternations from excessive heat to intense cold, and even the very weight of the masses themselves, but recently crystallized, could not fail to produce explosions and downfalls, and consequently fragments, which, in reuniting by means of the crystallization of the fluid substances which surrounded them, have given birth to some of the rocks termed *variegated marbles* and *pudding stones*. These rocks differ from porphyries, in this, that they are composed of fragments of other masses already crystallized, while porphyry consists of crystals which have been formed in the midst of the cement which unites them[p]; hence the cement of porphyry should be designated only under the name of basis. The conglobated rocks differ from the flint, (*grès*) in as much as they contain larger grains, or do not present regular homogeneous beds, or a foliated structure.

Conglobated rocks.

Custom appears to have appropriated the word *Brèche*, borrowed from the Italian, to aggregations of fragments of

Brèche, or variegated marbles.

[o] Saussure. Voyages, § 19. Faujas, Essais, ii.
[p] Saussure, Voyages, § 149.

calcareous rock, while the term *pudding stone*, for which the more classical appellation *allatoides*, may be substituted [q], appears to be reserved for rocks formed by the reunion of a great number of small *flints* [r]. It would be better to call "*Brèches*" the aggregations of angular fragments, and "pudding stone," those of rounded fragments, which probably have been rolled along by the waters [s]. The etymology even of the term in Italian, *Breccia*, borrowed from the Goths or Lombards [t], indicates a violent bursting. Pudding stone.

We may easily imagine, that these assemblages would vary in a thousand ways, either with respect to the nature of the reunited fragments, or of the cement which unites them. Of all the substances, however, which serve to conglutinate the fragments of primitive rocks, it is quartz, or siliceous earth, which is most abundant, and of most frequent occurrence. This element, which appears coexistent with our globe, may be considered as the source of all crystallized formation. Sometimes the brèches, in their turn, have been reduced to fragments, which, agglutinated by a new cement, have produced brèches composed anew, which have been called *double brèches*. We place next to these brèches, and among the conglobated rocks, those which the naturalists have called *Amygdaloïdes*, from their similarity to almonds imbedded in paste. The amygdaloïdes are composed of any paste whatever, in which are found knots or glands of the same substance, or of another. The whole is united by a confused crystallization; sometimes the spaces occupied by the knots, are found empty, the substance which once filled them having been destroyed by an unknown cause; this makes the amygdaloïde resemble porous lava. It is extremely difficult to distinguish the amygdaloides from certain varieties of porphyry. Without involving ourselves in discussions to which the formation of Amygdaloïdes.

[q] Du mot Grec αλλᾶς, genitif αλλᾶδος. (The genitive of αλλᾶς is αλλᾶνος, T.) poudingue.

[r] Saussure, § 197. Romé de l'Isle, Cristallographie, ii. 573.

[s] Delamétherie, Théorie, § 531. Comp. Haüy, iv. 463.

[t] Du verbe *Brechen*, Allem. *Brekke*, Dan. *briser*, *rompre*, French

conglobated beds has given rise, let us proceed to the examination of *stratified rocks*. In order to shew how vague are the limits between the productions of pure crystallization and those of stratification, let us be permitted to have recourse for a moment to an hypothesis borrowed from chemistry.

Stratified rocks.

The elements of which the rocks are formed, were undoubtedly once in a fluid state; this condition is necessary to render the aggregation of so many different substances possible. But the state of solution in which these substances existed, presented two modifications.

Chemical and mechanical solution.

Chemical solution differs essentially from *mechanical solution*; the latter exists when the integral particles of a body are separated one from the other, and suspended in a fluid; on being deposited according to their specific gravity, they form a *sediment;* on the contrary, by chemical solution, the integral particles are not only separated from one another, but are combined with the solvents; and in uniting, according to a new development of affinities, independently of their specific gravity, they afford a *precipitate.* Every crystallized substance is formed by chemical solution, and by precipitation; this character belongs, in the whole force of the term, to primordial rocks; but we have seen how crystallization lost by degrees its simplicity, and, if we may use the expression, its primitive energy. We have also seen how the crystallized texture has been succeeded by the foliated and the compact structure, which, in becoming larger and larger, seems to indicate a regular scale of chemical precipitations, gradually approaching to the nature of mechanical sediments. There can be no doubt, that the most immense of all fluids, the ocean, suffered a gradual decrease of its waters; the primordial mountains first reared their summits, then the earth began to swell up out of its chaotic state. Organic beings were then in existence; these were marine animals. The chemical precipitation continued, but, at the same time, the first mechanical sediments began to be deposited; the two precipitates were mixed, sometimes in great confusion, together,

Thus arose the *rocks* of *transition*, which are found on the sides of the primordial mountains, and sometimes at their base, in which we observe the first animal remains. The waters having gradually subsided, the globe from a shapeless chaos, takes the appearance of one vast sea, from which there arose on all sides, the primordial mountains, flanked by rocks of transition. Rocks of transition.

This is the Neptunian age, the second geological era. The sediments of the mechanical solutions alternated with the chemical precipitations; the solvent having gradually lost its original power, chemical action insensibly gave way to that which was purely mechanical. This Neptunian age gave birth to *stratified* mountains and rocks, understanding by the word *stratum* a bed of homogenous substance. This term, borrowed from the Latin, is not then precisely synonymous with *bed* or *layer*; a stratum differs still more from a *lamina* or *plate*, terms made use of in speaking of the texture, that the substance of certain rocks present, even in their minutest fragments. Stratified structure.

The hypothesis we have just now traced, exhibits the difficulties which geologists have met with in their attempts to classify stratiform rocks. In the *calcareous rocks* especially, the compact structure and the stratified are blended together by innumerable shades. Even in the same rocks, and notwithstanding its being completely homogeneous, we find the upper part containing petrifactions belonging to marine animals, while the lower beds are entirely free from them; but amongst the decidedly stratified rocks, we should place nearly all the aggregates of sulphate and carbonate of lime, known under the name of *lime-stone*; then the *secondary marbles*, which owe their earthy fracture to large quantities of argil, and their colours so agreeably varied to the presence of oxide of iron; *ruiniform marble*, which, according to Dolomieu, was a calcareous argillaceous stone, uniformly coloured, but while drying cracked into fissures; and these, filled by the transuding of the calcareous matter, have formed the appearances of ruins and land- Stratified calcareous rocks. Marbles ruiniformed, shelly, &c.

scapes, which are so much admired [u]; lastly, the *shelly marble*, composed of an infinity of small shells united by a calcareous cement. The *fœtid stone*, or *swine stone*, which in Norway forms of itself a little island, is only carbonate of lime, penetrated by bitumen. Calcareous substances predominate in the stratified rocks; the capital of France, with its palaces and temples, is built of calcareous stone, almost entirely composed of two kinds of shells: the cerites, (cyrithium,) which forms the upper masses, and the miliolites, (miliola,) which abounds in the deepest beds [x]. These rocks readily indicate the rank which belongs to them; but what rank can be assigned to the calcareous stone which presents itself under the form of *chalk*, and which occupies such vast belts throughout the globe? From its purity, it is almost a simple substance, containing only lime, carbonic acid, and phosphoric acid. From the small number of marine animals which it *immediately* contains, it resembles the primitive rocks from which its earthy consistence, destitute of the least appearance of crystallization, seems to keep it perfectly distinct; finally, the layers of large flint so frequently met with amongst beds of chalk, clearly indicate that they have been formed by deposit, and these beds inclose a great many marine animals of species which no longer exist [y]. It appears that the chalky state of the calcareous matter is owing to some particular causes, to investigate which is the province of chemistry.

Chalk.

Aluminous earth enters into a great number of stratified substances; *clay*, which occupies great spaces on our globe, is properly a mixture of silex and alumina, modified by the accidental presence of magnesia, iron, and other substances. Clay is found in *mounds* and in *rocks*; it seems natural to us to suppose in general, that these last may be formed by the hardening, or rather by the confused crystallization of argillaceous earths, mixed sometimes with grains of quartz.

Argile or clay.

[u] Dolomieu, Journal de Physique, Octobre 1793, p. 285, et suiv.

[x] Lamarck, Mémoires sur les Fossiles des Environs de Paris. *Annal. du Muséum d'Hist. Natur.*

[y] Comp. Brongniart, Traité de Minéralogie, i. 208—210.

But argillaceous earths may be formed also by the decomposition of rocks; such would be, according to Werner, the origin of potter's earth, which he places among the ternary earths or those of alluvion. All argillaceous soils have, without doubt, often changed their situation, their layers gliding easily one over another; their principal situation, however, is in the secondary rocks; they are found alternately with the free-stone, sand, and shell limestone.

Lithomarge, distinguished by its feeling greasy, and adhering to the tongue, by the fineness of its grain, and by its fusibility into a spungy mass, is the only clay which is found in the clefts of rocks in primitive formations. This is the substance to which several nations of America, Africa, and Siberia, have recourse to appease their hunger, or rather to beguile for a moment the cravings of their digestive organs [z]. Amongst the other kinds of clay, we distinguish for their utility those employed in the operations of the potter and the fuller, the different boles and ochres; the slate, which is of such service in roofing houses, and which is only indurated clay, in the form of schist or in laminæ. Slate, which is discovered in great blocks, has so foliated a texture, that the workman needs not exert any attention to catch the joints of its laminæ; wherever he places his chissel, he is sure of hitting a division. A quality common to all clay, is that of furnishing subterraneous reservoirs to fountains and springs; the best water is always found in argillaceous soils. Slate.

Fermenting clay forms an exception: as it is mixed with quartz sand reduced to fine powder, it imbibes water, swells up, and raises with great force houses, masses of rock, and whole fields; when the clay is dried, they sink down to their first level. The consequences of these unlooked-for throbs and heavings of the soil are very formidable in Sweden, and in Russia, especially when the clay in swelling happens to freeze at the same time [a]. Such devastations, arising from Fermenting clay.

[z] Humboldt, Tableaux de la Nature, ii. 191. Georgi, Description de la Russie, iii. 202, *sqq.*

[a] Waller, Minéralogie, i. p. 34. Georgi, Russie, iii. 201.

a cause apparently so weak, will assist us in conceiving of the revolutions which similar fermentations probably accomplished at the epoch when mountains were formed.

Marl. *Marl* is a clay united to a greater or less quantity of calcareous earth, often with quartzy sand, and sometimes so impregnated with bitumen, as to take fire of itself[b].

(Grès.) Sandstone. Siliceous substances are also deposited in beds. *Sandstone*[c] is composed of small grains of quartz agglutinated by a clayey, calcareous, or siliceous cement. It is the most common of all the stratified rocks. It forms the ordinary transition between the primitive and secondary mountains; in this situation it is found in parallel strata, and is but little mixed with heterogeneous substances. But it is met with also at a distance from the primitive mountains, and seems to have been formed at all the geological periods.

There is, as appears to us, a very sensible gradation in the different formations of "grès" or sandstone, from the *glossy* kind, which nearly approaches the primitive quartz, to the *pulviscular* species, in which the granulated structure becomes perceptible only by exposure to heat.

Recomposed granite. The *recomposed granite*, or the *sandstone (grès) of the coal mines*, is an aggregate of minute fragments of the ancient granite rock, united by cement of any kind, and sometimes so exactly resembling the texture of ancient granite, as to deceive naturalists themselves. But as the beds of these secondary granites alternate with those of coal, it is evident that they have a much more recent origin than the rocks of whose wrecks they are composed.

We are tempted to notice at this epoch, the enormous blocks of friable granite with which the marshes of Finland are covered, and from among which they have chosen the rock that serves as the base to the statue of Peter the Great. This granite, named *rapakivi*, in the language of

Rapakivi.

[b] Guldenstedt, Voyage dans le Caucase.

[c] Wherever the word "grès" is met with, it is best translated by the word "sandstone."—T.

the Fins, forms no contiguous mountains nor earth; it is decomposed very slowly [d].

The formation of porphyries is continued through the period of stratification; it has principally produced jaspers and quartz-agates.

The decomposition of stratified rocks, and the reunion of their fragments, or of those even of the most ancient rocks, by a stratified gluten or cement, forms what we call the *conglomerated rocks*. This formation appears to extend through a variety of periods, and to present a long series of shades which it is almost impossible to define. The *brèches*, or variegated marbles, and *pudding-stone*, composed of flint, jasper, shell marble, and others which belong to this class, are often confounded with the variegated marbles and pudding-stones composed of parts of crystallized rocks. The countries which have been most carefully examined with this view, namely, Thuringia and Silesia, present no other constant rule than the identity of the conglomerated fragments with rocks, either crystallized or stratified, which border upon them. The *pale-red* of Thuringia is a variegated marble of sandy quartz, in which are found granite, porphyry and schists, according as the neighbouring mountains contain them [e]. In Silesia *conglomerate-rocks* accompanying the primordial mountains, vanish when they disappear, and contain only fragments analagous to the stones which compose them [f]. At the foot of Mount Altai, in Siberia, we find whole mountains of quartz and jasper in small fragments conglomerated by a cement sometimes quartzeous, and sometimes argillaceous [g]. In Chili, enormous masses of pebbles reunitted by a black clay, rest upon the most elevated of the Cordilleras [h]. How are we to trace

Conglomerated rocks.

Different situation of these rocks.

[d] Bergmann, Géograph. Physique, i. 214. Comp. Patrin, Dictionnaire d'Histoire Naturelle, de Déterville, x. 81, au mot *Granit d'Ingric.*

[e] Heim, Correspondance de Zach, vi. 535.

[f] Léopold Buch, Description Géognostique de Landeck, p. 19. Id. Observations Géognostiques, vol. i. passim.

[g] Schangin, dans le Journal des Mineurs. (Bergmannisches Journal,) 1791, vol. i. p. 83, 89.

[h] Molina, Histoire Naturelle du Chili, p. 83. (trad. All.)

the innumerable formations which have successively produced these beds of broken remains spread over the whole surface of the globe?

Conglutined rocks, basalt.

We have not been able to comprehend in any of the preceding classes, a species of rock which is evidently formed by an operation different at the same time both from crystallization and stratification. We allude to the celebrated *basalt*, which has been the subject of so many discussions among geologists, and which has made them split, as it were, into two churches, each attached to its particular opinions with all the keenness of theological zeal.

These rocks, compact or porous, assuming prismatic or globular forms, or without any definite form, black, brown, greyish, and bluish, resemble in their texture corneous or horny rocks, and those which Werner designates *primitive trapps*. Silex and iron appear to be the principal chemical elements of basalt. So are they equally of trapp, but exposed to strong heat, the trapp affords a glass of a greenish transparency, whilst that of basalt is black and opaque. Besides, the basalt incloses crystals of "peridote," which are not found in the trapps[k]. The most striking character of basaltic rocks is their configuration. Nothing of this kind is more celebrated than those prismatic columns, of an immense height and thickness, of which the cave of Fingal in the island of Staffa is composed.

Chemical nature of basalt.

Configuration.

On the coast of Ireland, is another admirable collection of basaltic rocks, placed horizontally, and forming together what is called the Giants' Causeway. Masses of a similar description, though less considerable in size, are to be seen in Iceland, and are called in that country the Walls of the Devil. It has been remarked, particularly in the cave of Fingal, that though the prisms themselves are unequal, the faces of each are equal to the corresponding faces of the adjacent prisms, that the inequalities which are in relief upon the top or end of one of the prisms, are adapted to the depressions or little concavities, on the top or end of the next opposite prism, as if the one was moulded

[k] Faujas Saint-Fond, Géologie, ii. 269.

into the other; lastly, it is worthy of notice, that in the island of Staffa, where the prisms are raised one upon another, like a series of columns, the convex base of the one is inserted into the concave summit of the other; so that the columns appear to be articulated. Even when the basaltic rocks present themselves under a less regular structure, their position alone is sufficient to attract the particular attention of the naturalist. Those masses which, in a confused manner, lie over granite, gneiss, the primitive and secondary schists; those summits, which, sometimes conical, sometimes pyramidal, shoot up, in an insulated form, above rocks of a totally different nature; those cements which unite the basalts to various crystallized rocks; the successive transition of argillaceous siliceous schist to basalt, and from basalt to a kind of schorly rock, named *grunstein*; lastly, the numerous instances of the disintegration and decomposition of basalt itself, imparting fertility to the soil of the earth;—these are facts, the explanation of which, has for many years exercised and baffled the ingenuity of geologists. Position of basalt.

The *volcanists*, with Desmarets, Faujas Saint-Fond, and Dolomieu at their head, regard basalt as lava melted by the heat of a volcano, and which, while slowly cooling, has acquired by contracting those prismatic forms by which it is distinguished[1]. But this explanation labours under great difficulties. We ask the volcanists, Why these supposed lavas have an appearance similar to rocks, the aquatic formation of which is generally admitted? Why do they present no trace, either of vitrification, or of tumefaction? Why do they envelop untouched crystals, and other substances which must have originated from a state of fusion? Dolomieu answers, that the heat which melted these basaltic lavas, had very little intensity; that the fusion of these substances was only a simple dilatation, which, in separating the particles, allowed them merely to glide one over another, without, in any degree, changing their Of the volcanic origin of basalt.

[1] Dolomieu, Mémoires sur les îles Ponces, p. 100, *sqq.* Desmarets, Memoires de l'Acad. des Sciences, 1771, p. 273. Faujas Saint-Fond, Histoire Naturelle des Laves Prismatiques, &c.

nature. He supports this opinion by his own observations; according to which, the ordinary lava, even while it is flowing, is sufficiently firm and cool on its surface to admit of being walked upon without much inconvenience [l].

Facts opposed to the volcanic origin.

A multitude of other facts, however, seem to leave no subterfuge to the volcanists. In the first place, the basaltic cones, placed above all kinds of ancient and secondary rocks, and often forming the most elevated summits of chains of mountains, present, from their situation, from their entire structure, and from the absence of craters, characters very contrary to those of lavas and volcanic accumulations. Basalt is decomposed daily, which happens to no species of lava. In Ringuerike, in Norway, the soil appears almost throughout entirely to consist of decomposed basalt. Near Christiania, small fragments of this rock are spread over the fields, under the conviction, that it will form an earth proper for cultivation [m]. If we examine the texture of these rocks, we find it very sensibly approach that of the schistous porphyries and *grunstein*. Upon the Meisner in Hesse, we have observed, with a great deal of attention, the transition of basalt into grunstein [n]. The third fact, which is inconsistent with the volcanic origin of basalt, is its relative position in regard to coals. Not only in Hesse does basalt cover an immense bed of coals, but in Sudoroe, one of the Feroe Islands, a mine of coal is seen in the midst of the basalt [o]. It is evident that these masses of coals would have changed their nature considerably, if the lava in melting had flowed around them.

Neptunian origin of basalt.

The Neptunian origin of basalt appears to be attended with much probability. Bergmann, who was the first to prove by analysis the identity of trapp with basalt, is content with supposing, "that the substance of basalt, penetrated and softened by humid vapours, was converted

[l] Dolomieu, Journal de Physique, Fructidor, an ii. p. 408. ibid. Pluvoise, méme année, p. 118.

[m] Strom. Description du Canton d'Eger, p. 47, *sqq.* (in Dan.)

[n] Daubuisson, Traduction de la Théorie des Filons, p. 94, note 2.

[o] Mem. de la société d'Histoire Naturelle de Copenhague. See in the course of this work the description of the Feroër Islands.

into a clammy and liquid mass; that this mass having, in the progress of drying, suffered contraction, but not equally throughout the whole, had formed ruptures, and that it was thus subdivided, *with a kind of regularity*, into prisms of different kinds [p]."

Hypothesis of Werner.

A celebrated mineralogist, Werner, from considering the singular nature of basaltic rocks, and particularly the position of those of Saxony and Bohemia, thought that he had discovered, that the formation of these substances constitutes a distinct epoch, and requires causes quite different from those which have produced the ordinary kinds of earths and rocks. This philosopher imagined that a mechanico-chemical solution of a particular nature had once covered the globe. This solution produced precipitates analogous to its own nature; at first, gravel, clay, and sediment, purely mechanical; very soon after these, came the argilo-siliceous schists, named *wackes*, which already indicate the commencement of confused crystallization; then appeared the basalts. The mass of these being deposited upon almost the whole of the surface of the globe, the solution arrived at a state purely chemical, and afforded nothing but crystallized precipitates, such as the schistous porphyries, and the rocks called greenstein [q].

According to this hypothesis of Werner, there is a possibility of explaining why isolated basaltic columns are found projecting from the midst of a soil of a different nature, for we may conceive that the parts the least crystallized of the basaltic solution, that is to say, the parts mixed with clay and gravel, after having been deposited and dried, were again decomposed and carried along, with other earths, by currents of water, far from the sides of the mountains which once were covered with them. In some places, this mass of decomposed basalt is extended more equally over considerable tracts of ground. The masses

[p] Bergmann, De Productis Vulcaniis.

[q] Werner, Classification des Roches, &c. &c. Daubuisson, Journal des Mines.

of basalt, which are not decomposed, have at the same time preserved the rocks which they covered from this slow disintegration, to the action of which almost all the ancient mountains are subjected. Thus it is by the continued removal and disappearance of the lower basaltic strata, that the detached cones have acquired their particular form, and that singular position and appearance which astonish the eye of the beholder.

This hypothesis of Werner, which more multiplied observations will either confirm or overthrow, fully explains only the position of basalt, and not its origin; we can, even while we admit the hypothesis of Werner, ascribe the origin of the solution of the constituent parts of basalt to whatever cause we choose; it is even very likely that caloric has been the principal agent in bringing to a state of fermentation and fusion those substances, probably crystallized, which furnished the materials of that solution; but the fermentation and the fusion, which have been followed up by a new coagulation of particles, and by their contraction into prismatic forms, have no connection whatever with the system of phenomena arising from the agency of volcanos actually burning, or of other similar ancient volcanos, however powerful they may be supposed. The polar magnetism, which Haüy has observed in basalts[r], seems to indicate, that they were originally trapps, in which a slow and uniform dilatation of particles has developed the magnetic fluid. It is desirable that we should observe the direction of the basaltic colonnades, and the position of each prism in relation to the equator and the magnetic poles.

Of the coagulation of basalt.

Circumscribed as we are by the limits of our work, we must relinquish this interesting discussion concerning coagulated rocks, and proceed to the consideration of masses formed by *accumulation*. This is a portion of the globe which we may be said to have under our own eyes.

[r] Traité de Minéralogie, iv. 485.

Sand, gravel, some transported clays, that is to say, those which, by gliding and rolling, have changed their situation, and amongst which Werner places potter's earth; *tufa*, or stony substances formed by incrustation, such as the stalactites of caverns; the "*sinter*," or stony deposits of running waters; *breccias*, or variegated marbles of ternary formation, that is to say, older fragments of rocks united by a cement of tufa; *marshy-ochre*, although formed by chemical precipitation; some bituminous and aluminous earths, vegetable earth, and the *mud* of marshes; *turf*, composed of vegetable remains recently buried, less decomposed, and less impregnated with bitumen than coal; *bituminous fossil wood*, a substance which appears to be incipient coal, and which even in some places nearly resembles true coal; these are the materials which generally constitute *earths of accumulation*. We shall develop the origin of each of these substances, in tracing hereafter the history of the changes which have taken place on the surface of the globe. Substances projected by volcanos form the seventh class of solid masses which we have to consider. Earths of accumulation.

Amongst the *volcanic productions*, there are some which have undergone an igneous fluidity; these are called *Lavas*, in the proper sense of the word. We have just seen that it is among these substances that several French mineralogists place the basalt, which other naturalists consider as having been formed by the agency of water. We have considered these rocks as the produce of a formation anterior even to the seas, and before the existence of volcanos; and we should consider it a most arbitrary arrangement to rank amongst the substances thrown out by volcanos, one which forms no part of any stream of lava that has ever been observed. It is certain, however, that many true lavas have for their base petrosilex, feldspar, granite, or rather amphigene*, and other stony substances, which have preserved their appearance of stone, and which Volcanic productions. Stony and vitrified lavas, &c.

* Haüy Minéralogie, iv. 493. Dolomieu, Journal de Physique, Pluviôse, an. ii. p. 105.

even inclose pure crystals; but these lavas never assume the regular form of basalt[t]. Other lavas have been vitrified, as the *obsidian*, or *agate of Iceland*, which has completely the appearance of glass. The volcanic glass has often an enamelled or pearly appearance, and is found in a capillary form.

Pumice stone.

The *pumice stone*, or *pumiced lava*, is the best known of volcanic productions. Dolomieu considers it as the produce of foliated granite and micaceous rocks, or even of granites, properly so called. "The component parts of these rocks have the property of mutually serving as fluxes, and have been able to undergo, by the action of fire, a demi-vitrification, which may be compared to calcined matter, or frit, a little swelled[u]." This opinion appears to be true as to certain kinds of punice stone, but there are others which are produced from magnesian rocks, and especially from asbestos, or decomposed amianthus[x].

Scoriæ or dross.

The different *scoriæ* are substances strongly vitrified, which swim sometimes upon the torrents of lava, and sometimes are thrown out like hail around the volcano.

The *volcanic sands* appear to consist of lava scorified to the last degree, or of scoriæ decomposed after being ejected.

Pouzzolanes.

The *pouzzolanes* have not, like lava, experienced an igneous fluidity; they are substances of a more argillaceous nature than those which have formed the lava: having less sulphur in their composition, they have been able to resist the action of fire, which, instead of scorifying them, has only served to calcine and burn them. Heavier than the scoriæ, they fall near the centre of the volcanic mountain. United to lime, they form a cement of the greatest hardness and durability, which the Romans used in preference to every other in the construction of their aqueducts.

Volcanic ashes.

Volcanic ashes are discharged from the craters, in the

[t] Comp. Faujas Saint-Fond, Géologie, ii. part. 2.

[u] Dolomieu, Voyage aux îles Lipari, p. 6.

[x] Bergmann, De Productis Vulcaniis. Spallanzani, Œuvres, ii. 225, trad. de Senebier.

midst of a column of smoke, and are then driven by the winds to great distances. Those of Etna are carried to Malta, and some say even to Africa. When these ashes are still suspended in the atmosphere, and when the vapours, which, at the same time, are dissolved in it, happen to condense, the mixture which thus takes place occasions those earthy showers which fall sometimes at a great distance from the volcanos themselves. These ashes, from the extreme minuteness of their particles, introduce themselves everywhere, enter into the closets for keeping provisions, where they vitiate every article of food; but this inconvenience is compensated by the advantage which accrues from their fertilizing the grounds, ravaged by burning torrents of lava[y]. The heat of the volcanoes produces by sublimation, different substances, such as sulphur, muriate of ammonia, sulphuret of arsenic, and of iron.

Volcanic *tufa* is a substance produced by the agglutination of volcanic ashes, or fragments of scoriæ. The muddy eruptions which take place in certain volcanos may be considered as the principal cause of the formation of volcanic tufa; masses of clay or of liquid mud, in rolling over the cinders thrown out by the volcanos, incorporate with them[z]. At other times, the volcanic substances, in flowing into the sea, may be agglutinated there by a stony cement, held in solution by the salt water[a]. Volcanic tufa.

We shall not enter into a detailed explanation of the substances contained in lava, the origin of which still perplexes the naturalist; but we ought to notice, in a few words, *altered* or *decomposed lava.*

It is an important, but obscure and difficult question, whether lava, by the action of air and water, is reduced into earth, or becomes, at least, partially softened. Italy furnishes examples favourable to this opinion; Iceland offers proofs to the contrary. The probability is, that no vitrified lava is decomposed, but that which has been cal- Decomposed lava.

[y] Dolomieu, Mémoire sur les îles Ponces, p. 336, *sqq.*

[z] Dolomieu, Voyage aux îles Lipari, 56.

[a] Delamétherie, Théorie de la Terre, ii. 482. deuxième édition.

cined or changed by the action of the sulphureous acid vapours The mine of alum of La Tolfa, in the ancient Roman State, supplies us with an example of this; it is a lava, which, being decomposed by the sulphuric acid, is become white and friable [b]. Bergmann exposed some calcareous blackish and compact lavas, which came from Vesuvius, to the vapour of sulphuric acid; they acquired in a few hours the appearance and texture of chalk, similar to that in the neighbouring rocks of Solfatara [c]. There are naturalists who consider all lavas, even those most strongly vitrified, as penetrable by the acid gases; the sulphuric acid dissolves at first the iron, afterwards the bituminous earth and the lime; so that quartzeous earth, unchanged by acids, but attenuated and laid open, is at length carried away by the waters [d]; but these are possibilities, rather than ascertained facts. We conceive, at least in general, that the oxygen of the air has very little influence upon the lavas, and that the action of sulphuric, carbonic, and other gases, must be circumscribed to a small number of places.

It is proper, after volcanic substances, to mention those which owe to the action of subterraneous fires their deposits of coal The best known is that which is commonly called *porcelain jasper* [e].

Bolides. Stone showers.

The atmosphere has at all times contributed to augment the number of the solid substances of the globe. The *showers of stones* described as prodigies by many Greek and Roman historians, have been finally placed beyond the reach of doubt by the enlightened observations of Biot, Chaldini, and other philosophers. All these substances thrown down upon the earth from the clouds, contain the same elements of silex, iron, and nickel. They seem to be only the nuclei, or kernels of those balls of fire which we often see traversing the atmosphere with a dazzling bright-

[b] Dolomieu, cité par Haüy, Minéralogie, iv. 505.

[c] Bergmann, Géog.-Physique, ii. 197, en Suédois.

[d] Faujas Saint-Fond, Minéralogie des Volcans, chap. xix. p. 374.

[e] Thermantide porcellanite de Haüy, iv. 510.

ness, and disappearing in the twinkling of an eye. Thus the *bolides*, or atmospheric stones, should be concretions formed by the elementary gases, and perhaps by an effect of electricity; but they may also be regarded as so many satellites, or diminutive moons, which, revolving round our planet, terminate their course by uniting themselves to it, when causes that are unknown, but easy to be conceived, have deprived them of a part of their centrifugal force. Has Dr. Franklin been wrong in thinking, "that there may have been a time when it rained stones as it now does water?"

It now remains for us only to take a rapid survey of the substances which are foreign to the mineral kingdom, and which are found inserted amongst those that form the solid crust of the globe. These substances deserve a particular section to be appropriated to them.

BOOK XII.

Continuation of the Theory of Geography. Of the Fossil remains of Organic Bodies, Vegetable and Animal.

THE remains of organic beings buried in the earth may be viewed as so many geological medals, but medals without a date. The difference of age and of origin between the secondary and the ternary rocks would be easily ascertained, if we could precisely and completely class the remains of organic bodies, each according to the earth or rock in which it is found; but this arduous undertaking, scarcely ever conceived by systematic geologists, has only of late become the object of researches that deserve to be called scientific [a].

General view. Organic fossil bodies may be distributed into three classes; *remains* which have preserved their natural state, at least in part; *petrified substances*, and *impressions*.

Fossil remains. The first class consists principally of bones, and even whole skeletons, which, after having been deprived of the skin and flesh that covered them, remain buried in the earth, or concealed in deep caverns. Sometimes they are calcined totally or in part, without having lost their configuration; sometimes they retain not only their texture, but even a certain portion of skin and flesh; we occasionally find them incrusted with a calcareous covering.

Petrifactions. *Petrifications*, taking this term in the ordinary sense,

[a] G. Cuvier, Extrait d'un ouvrage sur les espèces des quadrupèdes dont on a trouvé les ossemens dans l'intérieur de la terre. Paris, an ix. Et ses Mémoires dans les Annales du Muséum d'Histoire Naturelle. Lamarck, Mémoires sur les coquillages fossiles des environs de Paris. Annal. du Muséum. Blumenbach, Specimen Archæologiæ Telluris; See Gazette des Sciences de Gottingue, No. 199.

comprehend all the stony substances which have the figure of an organic body. There have been instances where a liquid impregnated with stony particles has flowed into a cavity formed by an organic body which had disappeared. In that case, the stony mass has flowed into the empty cavity, and assumed the exterior form of the organic body which was there before. If this body was, for example, a branch or trunk of a tree, the stone will have knots and wrinkles on its exterior; but in the interior it will exhibit all the characters of real stone. It will only be, according to Haüy, "the statue of the substance which it has replaced."

While the process of decomposition is going on gradually and obviously in a vegetable or animal substance, it is sometimes likewise surrounded and pressed on by a stony juice. As each organic particle dissolves and disappears, a stony particle replaces it. Thus, particle after particle, the stony substance gradually occupies the spaces left vacant by the progressive decay of the vegetable or animal parts; and, by being moulded in these cavities, it copies, feature for feature, the contexture of the organic body. This is the way in which it is usual to explain the formation of *petrified wood*, an imitation of the real wood so complete, that upon cutting it transversely, we distinguish the appearance of concentric rings, which in the living tree arise from its annual growth. Sometimes it is even in a state from which we can ascertain by the lineaments of the texture the species to which the tree belonged [b]. Petrified wood.

Mineralized bodies, and those which have been changed into bitumen or into coal, may be referred to the same system of formation. Thus, the *turquoises* for example, are the jaw teeth of some large sea animal; a metallic substance which has penetrated them, has been gradually substituted for the softer parts of the bone. Mineralized bodies.

Delamétherie justly observes [c], that the siliceous matter

[b] Mongez le Jeune, Journal de Physique, 1731, p. 255, et suiv. (Comp. Daubenton, dans les Leçons de l'Ecole Normale, tome iii. p. 393, et suiv.)

[c] Théorie de la Terre, tome ii. p. 513.

so abundant in many organic bodies, lies crystallized in the bosom of the earth, and produced a great part of the stony substance which constitutes petrifactions—for these being often of a siliceous nature, although found in the midst of clay, whence then could have come this siliceous liquid, if not from the petrified body itself?

Impressions. *Impressions* are found between the laminæ of certain argillaceous schists; they are the relievos or moulds representing skeletons of animals, particularly fishes, leaves, reeds, entire plants, principally of the fern kind. These last impressions have this peculiarity, that if one of the leaves presents a concave print of the face of the leaf opposite to that which bears the fructifications, (as generally happens,) the other lamina will present, not the hollow impression of the face of fructification, but the relievo of the same face, which is concave upon the other leaf. To all appearance, as Brugnieres explains it [d], the fern placed upon soft clay has been covered over again with a new deposit. Afterwards, this plant reduced into a carbonaceous substance, or penetrated by the minute particles of the schistous deposit, becomes incorporated and identified with it; and, as the surface of the fructifications is unequal, that opposite being more smooth, it is natural to imagine that there has been less cohesion between the clay and this smoother face. Hence the reason why this latter face generally presents itself, when the leaves of the clayey schists are separated. We shall now consider successively the different classes of fossil remains. The petrifactions of vegetables seem to belong to the quartzeous, aluminous, and magnesian schists, rather than to the calcareous rocks.

Petrified vegetables. The petrifying substance is most frequently of quartz-agate, onyx, or jasper [e], it is not uncommon to meet with petrifications which have been formed by pyrites [f]. We

[d] Journal d'Histoire Naturelle, No. 4. p. 125. et suiv.

[e] D'Argenville, Oryctologie, p. 355, tab. xx. Stoppen, Récréations Physiques, i. 702. Schulzen, sur les Bois pétrifiés. Dresde, 1734.

[f] Henckel, Pyritol. 221, 227, (en Latin.) Denso, Biblioth. Physique, i. 158.

have seen a piece petrified by pyrites on the one side, and by agates on the other [g]. Petrified vegetables in lime, in gypsum, and even in clay, appear to be less frequent. Fossil ears of corn, impregnated with silver, with copper, and with other metallic substances, have been found in Switzerland, and near Frankenberg, in Hesse [h]. Sometimes only the exterior forms of the vegetables are perceptible; at other times, the different rings of the wood and tissue of the bark are to be distinguished. The "osteocolles," or calcareous tubes, appear to be incrustations formed around a vegetable root, which, deprived of its nourishing juices, has at last completely disappeared. Petrified fruits are sometimes spoken of, but they are very rare. They have been found on heights, where now they do not grow. A trunk of a petrified tree has been met with upon Mount Stella, in the country of the Grisons, at 4000 feet above the level where the last shrubs grow [i]. Entire beds of petrified wood exist at the elevation of 1500 feet above the sea, near the town of Munda, in Spain [k].

Impressions of vegetables.

The impressions of vegetables are almost exclusively found in the marly and argillaceous schists. Those of leaves and branches are common. Some have been met with, which present to us the most delicate traces of the structure of flowers, amongst others, the *aster alpinus*, near Ihlefeld, in the county of Hohenstein [l]. Like petrifactions they sometimes represent indigenous plants, or such as are natives of neighbouring countries; but those that are found in Europe oftener belong to the tropical climates of India and America.

These vegetables are exotics.

Bernard de Jussieu had remarked, about a century ago, that the greater part of the fossil plants which are found in the bituminous schists of Saint Chaumond, near Lyons,

[g] Bergmann, Géographie Physique, i. 307.

[h] Scheuchzer, Oryctograph. Helvet. 209. Lehmann, Mémoires Physico-chimiques, (en All.)

[i] Mémoires de l'Academie des Sciences de Paris, an 1710.

[k] Hollmann, Philosoph. Transact. 1760, p. 506, *sqq.*

[l] Bergmann, Geog. Phys. i. 303.

were foreign to our climates. There was recognized there, in particular, the fruit of a *nyctantes*, the *polypodium*, and the *adantlum*[m]. In a marly fossil schist, covered over by the lava, Faujas Saint-Fond met with the impressions of gossypium, in the state of a tree, the liquidambar-styrax, the cassia-fistula, and other vegetables of tropical climates. This same observer discovered the fruits of the palmier-aréca in a deposit of decomposed fossil wood, named "*terre d'ombre*," near Cologne[n].

The German, Scheuchzer, who has given an *antediluvien herbarium*. Woodward and Lloyd, and many other philosophers, have proved the same circumstances as to the fossil plants of their country. Delamétherie has shewn, that the elastic fossil gum of Derbyshire was the cahoutchouc, which grows only in Peru. And the amber of Prussia is supposed to have been produced from the gum trees in the forests.

Bituminated wood. Bituminated wood, although buried at great depths, may be the production of some less ancient and less violent revolutions. Pieces of wood have been found, of which one end was in a natural state, and the other bituminated[o]. And it is remarkable that this wood is often of an indigenous kind. At Upsal is preserved a large piece of an alder tree, which was discovered in Scania converted into jet, having still the bark and buds very discernible[p]. Thus bituminated woods approach by degrees to the nature of *subterraneous forests*, or heaps of wood, which have been simply buried by some modern convulsion.

Shells. Amongst the remains of the animal kingdom, *shells* and *zoophytes* are the most abundant; they occupy immense spaces, but are principally found in the calcareous rocks. France furnishes us with the best known examples. The environs of Paris alone have supplied M. Lamarck

[m] Mémoires de l'Academie des Sciences, 1718.
[n] Delamétherie, Théorie de la Terre, § 1452.
[o] Lehmann, cité par Bergmann, Géog. Phys. i. 306.
[p] Bergmann, ibid.

with more than 60 species, and this philosophical classification has not nearly reached its limits [q]. We know that a vast bed of chalk, accompanied by banks of calcareous shell, extends from Rethel, through the departments of the Marne and the Aube, towards Sens [r]. The quantity of extraneous bodies which have been found in this belt of chalk, or in its vicinity, is very considerable. "In the environs of the town of Rheims, are found quarries filled with transparent belemnites, with sea urchins, echini, and with pyrites of different forms. There likewise are to be seen in mingled confusion, cornua ammonis, fossil talc, petrified wood, and pieces of potter's earth full of impressions of leaves." From Chalons to Rheims, the soil is mixed with chalk, and contains belemnites, pectines, echini, the teeth of fishes, and the broken points of echini. The canton of Courtagnon presents a bank of shells of several myriametres in length, and nearly two in breadth. It contains a quantity of fossils preserved entire, and some have even retained their colour and their polish. "More than sixty kinds are to be seen, such as purple oysters, pectinites, chamas, tellines, mytilus, cardium, cypræa, cornua ammonis nerites, sabotes, lepas, patella, archa, squalus maximus, and other animals, and also fossil corals [s]."

Below the town of Montmirail, between the farm of Tigecourt, and a hamlet called Le Faussat, at the confluence of the rivulet of Saint-Martin with the river called the Petit Morni, there is a very extensive bank of sand filled with fossil shells of every kind. This bank is five metres in height, and is covered with sixty-five centimetres of vegetable earth; below the bank of shells is another of yellow and grey sand, which is almost horizontal and parallel to the declivity of the soil. The quarries of Epernay, and of Dizy, along the Marne, furnish nearly the same

[q] Bruslé, Statistique du Département de l'Aube, p. 6.

[r] Description du Département de la Marne, par la Société d'Agriculture et des Sciences du Département, p. 46, et suiv.

[s] Coquebert-Monbret, Journal des Mines, No. 94, p. 316.

fossils, as well as petrified wood, which resembles the true chesnut tree. In the cabinet of natural history at Chalons, a shark's tooth is preserved incrusted in chalk, and a petrified echinus, found at the depth of twenty-seven metres. All the plains of what was formerly called the Isle of France, present vast banks of calcareous and sandy stones, filled with, or rather composed of shells, some belonging to the kinds which inhabit our seas, others similar to those which exist in fresh waters, a circumstance which proves a difference both in their age and their origin [t].

France still farther supplies an example of one enormous bed covered with no other substance than shells. I allude to the neighbourhood of Touraine, which is one continuous bed of broken shells, of about nine ancient square leagues in superficial extent, and at least 20 feet in thickness. The whole mass of shells is estimated at 170 millions of cubic toises [u].

Touraine.

Remarks upon the shells in Germany.

The other countries of Europe are not less abundant in fossil shells. Twenty pages would be insufficient to enumerate the places of Germany where they are found; but there is one general remark of the German philosophers which is highly deserving of attention. The calcareous rocks of transition, and the schists of the same formation, in the chain of Hartz, contain only zoophytes, such as the madrepores, millepores, and terebratulites; the stratified rocks, considered as the most ancient, contain also zoophytes, belemnites, ammonites, encrinites, pentacrinites, in a word, shells the most remote from the actually existing kinds [x]. On the contrary, the most modern calcareous rocks, those of Mount Bolca, near Verona, and the hills of chalk in England, and Zealand, inclose kinds approaching to those which now exist, such as the ostracites, pectinites, buccinites, nautilites, chamites, and others [y].

[t] Cuvier et Brongniard, Géographie-Physique des Environs de Paris. Annales du Muséum, xi. 293.

[u] Reaumur, Mémoires de l'Acad. des Sciences, en 1720, p. 404.

[x] Freisleben, Observations sur le Hartz, ii. 81.

[y] Steffens, Beytræge zur Innern, etc. p. 87.

The north and south of Europe do not yield to the central parts in this respect. The calcareous rocks of Rœtwick, in Sweden, at 3000 feet above the sea; the vegetable earth of Finland, and the argillaceous beds of the islands of Norway, abound in shells, some whole, others almost changed into earth [z]. Shells of the north and south of Europe.

In Italy, we see near Bologna a bed of sand formed of *cornua ammonis*, which are not one line in thickness [a]. In Greece and in Spain we often travel over nothing but shells. Ramond has found them in the Pyrenees, upon the summit of Mount Perdu, at the height of 10,578 feet; Lamanon, in the Dauphinese Alps, at 7,446 feet; Guerin, upon Mount Ventoux, at 6,162 feet; and Saussure, in the Alps of Savoy, at 6,104 feet; it may be affirmed, almost with certainty, that throughout Europe, wherever there is chalk, there also are shells [b].

Every thing concurs in leading us to consider the other parts of the world as perfectly similar to Europe with respect to the abundance of shells. The vast heaps of echini which exist in Lybia, and in Barbary, have been described by Shaw; and we know from Rœmer, that they are found in the gold mines of Akim in Guinea [c]. Mount Libanus is in a manner sown with echini [d], and Mount Carmel with petrified oysters [e]. In the chains which border the Caspian Sea, shells are found even at a height above the region of the clouds [f]. We see beds of them interposed amongst the rocks of Mount Taurus in Caramania [g]. The mountains of China, according to the Jesuits [h], are covered with them; Shells of Asia and Africa.

[a] Bergmann, Géograph. Physique, i. 287. Linné, Pontopp. Dan. &c.
[a] Comment. Bononienses, p. 66.
[b] Faujas Saint-Fond, Essai de Géologie, ii. 61, 66.
[c] Rœmer, Voyage, &c. p. 20. (in German.)
[d] Paul Lucas, Voyage, ii. 380.
[e] Corn. le Bruyn, Voyages au Lévant, ch. 59.
[f] Kæmpfer, Amœnitat, Exot. 430.
[g] Figueroo, Ambassadeur Espagnol, cité par Leibnitz, Protogea, § 23.
[h] D'Incarville, Philosoph. Transact. vol. xlviii.

and Siberia has offered to the Russian travellers not only calcined, but pyritized shells, and also madrepores[i].

The philosophical traveller Peron has seen the coasts of Timor, New Holland, and a great many other oceanic lands, composed in a great measure of accumulations of marine testaceous animals. With regard to America, we learn from Kalm, that the United States and Canada contain enormous beds of calcareous matter. We see Admiral Narborough seeking in vain, in the Bay of St. Julian, for oysters analogous to the shells of which he found the neighbouring mountains composed; and, lastly, in the centre of that hemisphere, M. de Humboldt points out to us the high chain of the Andes covered over with ostracites (petrified oyster shells) at an elevation of 13,200 feet.

Shells upon the Cordilleras.

The remains of other sea animals are less abundant[k]; next to the testaceous kinds, fishes are the most frequent. They are found in Switzerland, near Glarus, in the slaty schists; in Germany, in marly schist, and in the bituminous schist of Pappenheim; in the coppery schist of Eisleben; in the stinking schist of Ochningen; in Egypt and in Syria; in the calcareous rocks upon the coast of Coromandel, and in several mountains of China[l]. The place which has furnished the greatest number, is Mount Bolca, near Verona in Italy.

Fossil fishes.

France has furnished some very curious specimens; there has been discovered at Grandmont, at four leagues from Beaune, in Burgundy, a fish in a mass of grey calcareous hard stone. Another, which was 10 inches 10 lines long, has also been found in a solid bed of stone, at 17 feet depth, at Nanterre, near Paris.

These are the only two examples of this kind; the other fossil fish hitherto discovered, not being incrusted in the mass of the stone, but in the more recent layers. The fish

Fossil fish of Nanterre.

[i] Georgi, Description de la Russie, iii. 599, &c. &c.

[k] Humboldt, Tableau des Régions Equinoxiales, p. 126, 127.

[l] Scheuchzer, Piscium Querelæ et Vindiciæ, Zurich, 1708. Knorr, Lapides Diluvii Testes. Nuremberg, 1719. Tab. 17, 18. Gessner, de Petrificatis, cap. 27, p. 60, édit. de 1759.

of Nanterre appears to belong to the tribe of coryphenes, kinds similar to which live in the equatorial seas [m]. Other fossil fish have been found at Montmartre, and at the village of Devey-Lourane, in the department of the Ardèche.

The *glossopetræ* are sharks' teeth, (*squalus maximus*,) and are found almost everywhere, even adhering to the maxillary bone [n]. The calcareous rocks which border all the coasts of the Mediterranean, afford them in great quantities; they are frequent in Livonia, in the hills of Mount Ural, and in the steep shores which form the margin of the rivers of Siberia. Glossopetræ.

The fish, though there are some also found in calcareous rock and in freestone, seem to have been enveloped chiefly by the formation of the marly schists; but is it to the oil contained by the fish, that some of these schists owe their bitumen, and others their urinous odour? This opinion of Werner merits examination. General remark.

It appears that amphibous animals did not exist in a great number, till after the age in which the fishes were produced. Cray fish, however, occur at Pappenheim, Glarus, Verona, and in other places by the side of the fishes. An entire tortoise was found in the soft stone, near Berlingen [o]. In the environs of Brussels, of Aix, in Provence, and in the quarries of the great Charonne, near Paris, different kinds of fossil tortoises have been met with [p]; but the most remarkable amphibious remains are the different kinds of lizards, that are commonly called *fossil crocodiles*, though it has been demonstrated that they are of a nature very different from that of the crocodiles, and partly of a species as yet unknown [q]. The coppery schists of Thuringia, furnish specimens in considerable numbers [r]; and they Amphibious fossils. Fossil crocodiles.

[m] Faujas, Essai de Géologie, tome i. chap. iv. et les Annales du Muséum.

[n] Leibnitz, Protogea, § 26—31. Tab. vi. vii. et les Dissertations citées par Bertrand, Dictionnaire des Fossiles, au mot *Glossopetra*.

[o] Bergmann, Geog. Phys. i. 276.

[p] Faujas, Géologie, i. 187.

[q] Cuvier, Annales du Muséum, xii. 73, 145, &c.

[r] Miscell. Berolinens. 1710, p. 103.

are found at Elston, in England, imbedded in the clay; but the most celebrated are those which have been discovered in the vast quarries of Maestricht, beneath a great calcareous mass. The marine fossil animals are in a great measure foreign to the coast of those countries where they have been found buried.

These animals are exotic.

The Abbé Fortis has discovered that the petrified fishes of Mount Bolca, in the Veronese, had their corresponding living species in the seas of Otaheite [s]. According to Linnæus, the porpites of Gothland appear to be petrifactious from the medusas of India [t]. The madrepores, so abundant in the frozen solitudes of Siberia, exist only in the equatorial and tropical seas. The greater part of the petrified shells that are found in England, are now to be met with, occupied by living tenants, only in the Atlantic Ocean, towards the coasts of Florida [u]. Dicquemare found near Havre, a shell, which is now seen, in a living state, only at Amboyna [x] Scheuchzer has given the description of many of the fossil shells of Germany, which do not exist in a living state in our seas, or perhaps in any quarter of the globe. It appears, beyond doubt, that the animals of several fossil shells, such as the ortho-ceratites, the ammonites, the gryphites, the judaic stones, several echinites, and others, do no longer exist, or exist only in the unfathomable depths of the sea. The banks of these kinds of fossil shells, are called *pelagian*, whilst, under the name of *littoral banks*, are designated those containing indigenous shells deposited by the present sea.

Pelagian and littoral banks.

We cannot, however, with confidence assert, that there are any of them to which the living species bear a perfect resemblance.

But can this observation, which holds so generally true in Europe, and the north of Asia, be extended to Africa, South America, and New Holland? Do we find there

[s] Journal de Physique, 1786. Mars, page 162.

[t] Linnæus, Amœnitates Academicæ, i. p. 91.; iv. tab. 3.

[u] Kalm, Dissertatio de Ortu Petrificat. p. 7.

[x] Journal de Physique, 1776. Janvier, p. 39.

the shells and fishes of our northern seas? To this question no satisfactory answer can yet be given. The testaceous fossils that occur in Lybia, resemble the marine animals of the gulf of Arabia; but we are assured that at Fez, in Morocco, both European and American shells are frequently found mingled together [y].

Remarkable circumstances.

Many singular circumstances are connected with these monuments of the history of our globe. The petrified and perfectly preserved shell is often found close by the side of several others, calcined, worm-eaten, and destroyed. Here the beds of the shells lie horizontally, with the concave part upmost, and without any foreign mixture [z]; there, as is the case near Uddevalla, in Sweden, these remains are found in the midst of fragments of granite, of sand, and of clay, jumbled together in the greatest confusion [a]. Some fishes have been forcibly and suddenly enveloped in the substance which contained their impression, or their cast in petrifaction [b]. We can still perceive the violent and convulsive contortions into which these animals had thrown themselves to escape the terrible catastrophe of which they are the monuments. In some places, the proximity of these remains to a variety of minerals, present singular appearances; at Jarlsberg, in Norway, muscles have been found in a mine of loadstone [c], and petrified shells, with adhering threads of gold and silver, have been met with in England and in Siberia. The most uncommon objects of this kind appear to be the muscles that occur in cinnabar, completely filled with that metal [d].

Thus, before our stratified mountains, and the metals which they contain, were formed, before the fragments of these mountains, uniting together, produced rocks and earths of accumulation, the globe must have been covered

[y] Bourguet, Traité des Pétrifications.
[z] Kalm, Travels, &c. i. 292, (en Suédois.)
[a] Wallerius, Dissertat. de Collibus Uddewvallensibus.
[b] Voyez Piscium Querelæ et Vindiciæ, par Scheuchzer, &c.
[c] Cronstedt, Minéralogie, p. 224. (en Suéd.)
[d] Bergmann, Géog. Phys. i. 301.

in a great measure, and at different periods, sometimes with the waters of the ocean, sometimes with a body of fresh water, and, lastly, with several fluids of an unknown nature, impregnated with substances which have enveloped the madrepores, the shells of marine, and of fresh water animals, and the fishes, whose petrifactions or impressions we find heaped up one above another. In the immense succession of ages which these tranquil formations required, interrupted from time to time by violent revolutions, it appears either that the mammiferous animals, the birds, and the great cetaceous tribes did not yet exist, or that they existed in a situation which secured them against the effects of those catastrophes which buried the countless generations of the lesser sea animals in the bowels of the earth.

Remains of cetaceous animals.

There have not, at least, been found any remains of the mammiferous, nor of the cetaceous race, decidedly covered over with a regular stony bed. The instance of the bones of an elephant, found under a calcareous bank in England, requires to be more completely verified [e]. The fossil teeth of the *trichecus rosmans*, found in Eastern Siberia, and the skeletons of whales discovered at Quebec [f], and at Tistedal in Norway [g], were lying in beds of moveable earth.

Birds and insects.

Petrifactions and impressions of *insects* and *birds*, are less common, and seldom very distinctly marked. The accounts of honey-combs, petrified with bees, lava, and eggs, found in a cavern of Upper Egypt, requires additional confirmation [h]. The oldest remains of birds are met with in the marly schists of Pappenheim and Œhningen [i]. The others are in general only incrustations of calcareous tufa, and consequently of the last age of geological revolutions [k].

Remains of quadrupeds.

We proceed now to examine the remains of quadrupeds; these are found accumulated in regions where similar ani-

[e] Pennant's Works, xv. 158. Comp. Cuvier, Mémoires sur les Elephans Fossiles et Vivans. Annal. du Museum, viii. 41.

[f] Kalm, Voyage d'Amérique, &c. iii. 247, (en Suéd.)

[g] Pontoppidan, Hist. Nat. de la Norwège, i. 63, (en Dan.)

[h] Lippi, Mém. de l'Académie de Paris, 1705.

[i] Scheuchzer, Vindic. Piscium, tab. 2.

[k] Bergman, Géograph. Physiq. i. 274.

mals do not now exist. Some are buried deep in beds of gypsum, as the kinds now unknown, and which Cuvier may be said to have resuscitated, namely, the *palæotherium* and the *anoplotherium*, with their different varieties, found in beds of gypsum in the environs of Paris[l]; others are met with in beds of sand or marshy ground, as the greater part of the bones of elephants; the *megalonyx*, an animal unknown, but of the tribe of sloths, having the shape of an ox, and found in Virginia[m]; and the *megatherium*, discovered near Buenos Ayres, and which joins to a character approaching that of the sloth, the bulk of a rhinoceros[n]. There are some, indeed, which present themselves to view, accumulated in vast caverns, and destitute of any envelope; it is thus that the *fossil unicorn* has been found in the caverns of Harzdorf and of Baumann, in the mountain of Hartz, and the *fossil bear* in those of Gailenreuth and of Maggendorf, in the country of Bareuth[o]. The fossil remains of this genus are not less generally extended over the globe than those marine animals. The *fossil elephant*, which is of a kind as different from that of India and Africa, as the horse is from the ass[p], has left proofs of its ancient existence in all Europe, in Northern Asia, and in the New World. We know that Siberia annually exports a considerable quantity of fossil ivory[q]; a substance which abounds very much in that country. It is almost always seen where the water of the rivers undermine the light soils which form their borders. The islands of Lachof, situated to the north of Siberia, are, ac-

1st, In gypsum.

2d, In the marshes.

3d, In the caverns.

Fossil elephant.

In Siberia.

[l] Cuvier, Mém. sur les os Fossiles de la Pierre à Plâtre des Environs de Paris. Annal. du Muséum, iii. 275, 364, 442.; iv. 66.; vi. 253.

[m] Id. ibid. v. 358.

[n] Id. ibid, v. 376. Description des os de Megatherium, par Bru, ibid. 388.

[o] Blumenbach, Specimen Archæologiæ Telluris, l. c. id. Manuel d'Histoire Naturelle, 695, (en All.)

[p] Cuvier, Sur les Eléphans Vivans et Fossiles, Annal. du Muséum, viii. 265.

[q] Momotova kosti, c. à. d. os de Mammout ou Momot. *Momotova* est le génitif pluriel en Russe.

cording to a modern traveller, only heaps of sand, ice, and bones of elephants and rhinoceros, mixed with those of great cetaceous animals, and even, agreeably to the latest accounts, with the remains of gigantic birds.

There have even been found in Siberia, whole carcases of the elephant, which is named *momot* or *mammoth*, covered with their flesh and skin, preserved by the frost which prevails in these regions [r]. In Europe, it is Germany which has furnished the greatest number, "because," says M. Cuvier, "it is in this empire that there is no canton without some well informed person capable of making researches, and publishing whatever is interesting in his discoveries." The skeleton of the elephant found at Tonna, in Thuringia, was imbedded in a sandy marl, covered over with layers of calcareous tufa, which in that country fills the cavities of calcareous stratified earth [s]. In France, a great many bones of the elephant have been met with since the discovery of those in Dauphiny, which were taken at first for the remains of a giant, or of Tentobochus, king of the Teutons [t], until the appearance of those bones which were lately discovered in the forest of Bondi, and which are buried deep in a black earth, covered over by sand mixed with clay and marl [u]. Italy has furnished a harvest almost as abundant as Germany. The other countries of Europe are not without them, England contains several. Ostrobothnia supplies us with one specimen. If we pass the Atlantic Ocean, the New World presents three tracts of land in which they are found. In Iceland, one tooth of an elephant has been discovered [x]. North America contains some scattered bones, and several have been brought from the upland plain of Quito by Humboldt [y].

Fossil elephants in Europe.

In Iceland and America.

[r] Adams, Voyage à la Mer Glaciale, Annal. du Muséum.

[s] Freisleben, Description Mineral. du Canton de Burg-Tonna, dans le Magasin de la Science du Mineur, vol. x. p. 51.

[t] Faujas, Annal. du Muséum, ii. 24.

[u] Cuvier, Annal. du Muséum, viii. 21.

[x] Bertholin, Acta Medic. Hafn. i. 83.

[y] Humboldt, cité par Cuvier, Annal. du Mus. viii. 57.

Next to the mammoth, or fossil elephant, we should mention the *mastodonte*, an animal nearly similar to the elephant, and like him graminivorous, although its teeth are furnished with many elevations. This animal, which the Anglo-Americans confound with the true mammoth, of which there are five distinct kinds, all unknown in a living state [z], has left its imposing remains upon both continents, for it is to a species of mastodonte that we must refer, amongst others, the grinders, which are changed into turquoises, found near Simorre, in the department of Gers, and which had been at first attributed to an elephant [a]. It is upon the banks of the Ohio and of Hudson's River, in the United States, that the hugest remains of the mastodontes are found; they have also been met with in Lower Louisiana [b]. Humboldt has discovered the bones of another species in the high plains of Quito, at the foot of the volcano Inibabura, and in the place called the *Field of the Giants*, from 700 to 800 feet above the level of the sea. Mastodonte, a fossil animal.

The fossil bones of the rhinoceros and hippopotamus, belong to species different from those which exist in the present day. They are often found in the immediate vicinity of the remains of the elephants. The most remarkale remains of the rhinoceros is the head, which has been taken out almost untouched from the turf pits, on the Wiloui, a river of Siberia. Bones of rhinoceros, hippopatamus, &c.

Amongst the fossil animals called *tapirs*, there has been found a variety, whose dimensions are gigantic. Some kinds of animals now very small, and whose weakness leaves them an easy prey to the more powerful, appear from their fossil remains to have once rivalled the strongest animals. Of this number we have already mentioned two kinds, approaching to that of the sloth, one of which has Gigantic dimensions.

[z] Cuvier, Annal. du Muséum, viii. 412.

[a] Cuvier, Annal. du Muséum, no. 14, p. 132. Faujas Saint-Fond, Journal de Physique, 1794. Decembre, p. 445.

[b] Peales' Historical Disquisition, &c. London, 1803. Volney, Tableau du Climat des Etats Unis, i. 100. Cuvier, sur le Grand Mastodonte, Annal. du Muséum, viii. 270, *sqq.*

been found in Virginia, the other in the environs of Buenos Ayres; the first is the *megalonyx*, of the shape of an ox, the other the *megatherium*, which has the dimensions of an elephant [c].

Fossil remains of carnivorous and ruminating animals.

We cannot enumerate, kind by kind, the various animals of which fossil fragments are to be found, and we shall abstain from inquiring whether the carnivorous animals, of which the caverns of Germany contains so many remains, are different from the bears, the lions, and the hyenas of the present age, and from any attempt to resolve the doubts which still remain respecting the fossil fragments of ruminating animals, among which the *elk of Iceland*, and the great buffalo of Siberia, hold the first rank [d]. The variegated marbles of Gibraltar, Cette, and other places, exhibit also, under circumstances that are quite inexplicable, innumerable bones of ruminating animals, analogous to the living kinds in Europe. At the same time we must not omit to mention the curious discovery of the skeleton of an animal of the *opossum* kind, found in the plaster stones of the environs of Paris. This very particular species is now no where to be found but in South America [e].

Opossum.

These discoveries, though as yet scarcely commenced, have thrown already a new light upon the revolutions which our globe must have undergone, and upon the states which must have preceded the present course and constitution of nature.

Of the origin of bones in caverns.

How many species of animals are there extinct, and by what various revolutions! The animals, the remains of which are now found in caverns, evidently appear to have retired thither of themselves to seek shelter from some sudden revolution, the irresistible violence of which, notwithstanding, involved them in general destruction [f]. Were they flying from a sudden inundation? Did they implore

[c] See above, p. 277.

[d] Cuvier, sur les Os Fossiles des Ruminans, dans les Annal. du Muséum, xii. 333, *sqq.*

[e] Id. ibid v. 277—292.

[f] Blumenbach, Specimen Archæologiæ, etc, etc. l. c.

of these caverns protection from some baneful alteration of climate? Or did they use them as spacious cemeteries for the regular interment of their dead, according to the reported habits of the elephants of Africa? In every instance, the almost entire state in which many of their bones are found, and the nature of the calcareous tufa with which the others are surrounded, evidently shew the recent date of this last revolution of the globe.

Origin of the bones found in Gypsum.

The animals whose remains are found in such great quantities in gypsum, are generally of one single kind, or at least of one tribe. This circumstance occurs only in the islands or insulated continents; it would hence appear, that these animals inhabited small portions of land which at one period were engulphed in the sea[g].

Origin of the bones found in the light soils.

The light soils which fill the bottoms of the valleys, and which cover the surface of great plains, have furnished us with the single orders of *pachidermes* and *elephants*, bones of eleven species, namely, a *rhinoceros*, two *hippopotami*, two *tapirs*, an *elephant*, and five *mastodontes*[h]. All these eleven species are now absolutely strangers to the climates where their bones are found. The five mastodontes alone can be considered as forming a genus separate and unknown, but very nearly allied to that of the elephant. All the others belong to kinds now existing in the torrid zone; and three of these living kinds are found on the ancient continent, namely, the rhinoceros, the hippopotamus, and the elephants. The fourth, that of tapir, exists only in the new. The same distribution does not hold as to the fossil animals. It is in the ancient continent that the bones of the tapir have been dug up; and there have been some bones of elephants found in the new. These species, belonging to known *genera*, differ, notwithstanding, essentially from the known *species*; they must therefore be considered as particular species, and not merely as particular varieties. The subject cannot admit of any dispute as to the small

[g] Cuvier, Annal. du Muséum, iii. 386.

[h] Id. Annales du Muséum, viii. 421, *sqq.*

hippopotamus, and the gigantic tapir; it is also very clear with respect to the fossil rhinoceros, and extremely probable as to the elephant and fossil tapir. The great hippopotamus is the only one of the eleven quadrupeds concerning which there remain any doubts.

These different bones are buried almost every where in beds nearly alike. They are often mixed in confusion with some other animals as nearly resembling those of the present time. These beds are generally light, either sandy or marly, and always more or less near to the surface. It is probable, therefore, that these bones have been enveloped by the last revolution of the globe. In many places they are accompanied by the accumulated exuviæ of marine animals. But there are some places which do not afford any of these exuviæ. Sometimes even the sand or the marl which covers them over, contains only fresh water shells. Although a small number of shells attached to these fossil bones indicate that they have remained some time under water, no very authentic account attests that they are found beneath regular stony banks, filled with marine shells, nor consequently that the sea had covered them for a great length of time[1].

The catastrophe which has covered them over, would appear then to have been a great but transient inundation of the sea, if these bones had not been found upon the top of high mountains, where the present sea at least could not have reached in its most violent agitations. On the other hand, these bones presenting no trace of having been rolled up and down, occurring only fractured, as we find those of our domestic animals, and sometimes joined together in the form of skeletons, often even as it were heaped up in common cemeteries, clearly demonstrate that the catastrophe which has destroyed the living beings to which they belonged, must have overtaken them in the same climates where we meet with these records of their former existence. These two conclusions, drawn from evident facts, destroy

[1] Cuvier, viii. 266, 422.

the hypothesis according to which the extinction of these animals would be the immediate effect of a great revolution of the temperature of the globe; for such a revolution would have still permitted these animals to seek another habitation. Nothing besides in the structure of these animals positively announces that they could not have lived in a cold climate; only the quantity of nourishment which such huge animated masses required, and their numbers, proved by the existence of the carnivorous kinds, render it probable that the countries where we find their remains, once enjoyed a temperature, if not warmer, at least more favourable to vegetation.

Human bones.

The total absence of human bones in these different collections of remains, proves that man did not exist anterior to the last revolution of the globe.

Thus have we hastily surveyed the immense series of the solid substances which form the crust of our globe, from the granite summit of the Alps to the bottom of the deepest mines; and every thing we have met with has suggested the existence of a fluid substance, without which the solid masses would not have experienced either those decompositions, nor those re-unions of which we have perceived the most evident traces. Here then we shall close our *geological* observations, and proceed to *hydrology*, or the theory of the waters spread over the surface of the globe.

BOOK XIII.

Continuation of the Theory of Geography. Of Water in general. Of Springs, Rivers and Lakes.

Of water in general.

WATER, in its pure state, is a transparent fluid, without colour or smell, and possessing great mobility. It presents itself under three forms of aggregation, as a solid when it is *ice*; as a liquid, when it is called water; and, lastly, as a vapour or atmospheric gas. Water was long regarded as an element, but modern chemistry reckons among its triumphs the discovery of the elementary substances, of which even water is composed.

Water, in its state of purity, contains 85 hundreth parts of oxygen gas, or pure air, combined with 15 hundreth parts of hydrogen gas or inflammable air; but we very seldom find water perfectly pure, as it generally holds in solution siliceous, calcareous, and metallic particles, acids, and sulphur. The air is dissolved by water, which it dissolves in its turn, and in a still greater proportion. It is even probable that the whole earth, or at least the exterior crust of our globe, was once in a state of mechanical or chemical solution by the agency of an aqueous fluid. We wish to pursue a course independent of all system, beginning with those circumstances which are most easily observed, and advancing from the smaller to the greater objects.

Springs.

Springs are so many little reservoirs, which receive their waters from the neighbouring ground, through small lateral canals, and which discharge their excess either by overflowing or in some other manner.

The origin of springs cannot be referred to one exclusive cause: nature, simple in her general laws, avails herself of

a great variety of means; thus the precipitation of atmospheric vapours, the dissolving of ice, the filtering of sea waters, and the explosion of subterraneous vapours, all concur in the formation of springs[a].

Vapours attracted by high lands.

Mountains, as is obvious to the most superficial observer, attract the fogs and clouds which float around them. As the cold is increased in proportion to the increase of elevation, it necessarily follows that more snow must fall, and more will be formed on the mountains than on the plains. These are the two principal apparent causes which contribute to saturate mountains with the water which flows from them in all directions. But are these the only causes? Are we to believe that those extensive lakes which are met with at considerable elevations, and the glaciers which cover the Alps, have been gradually formed by the rain and snow, or must we admit that, at the origin of things, at the period when extensive crystallizations took place, the water united itself by a kind of elective attraction to certain substances, in preference to the rest of the earth?

Filtration of sea water.

The opinion of the ancients and of Descartes, who attributed the origin of springs to the filtration of the waters of the sea, is not entirely groundless. It is true, that all running waters have their sources far above the level of the sea. The direct filtration of sea water, can take place no where except in pools, which are separated from the ocean only by flat and sandy ground. But the phenomena of capillary tubes may obtain in the interior of the earth. The sea waters, deprived of their salt and bitter elements, may ascend through the imperceptible pores of several rocks, from which, being disengaged by the heat, they will form those subterraneous vapours to which many springs owe their origin. We may here quote the example of the Chartreux, who, seeing their springs dried up, and learning that thick vapours were observed to ascend from a neighbouring quarry newly opened, they bought the quarry, closed it up, and beheld their springs reappear[b]. A similar occurrence

[a] Bergmann, Géographie-Physique, i. 325—334.
[b] Perrault, Œuvres Diverses, p. 819.

happened in Sclavonia[c]. The change of the saline matter in sea water is satisfactorily proved from the diminution of the saltness in the springs, which evidently originate from such filtrations[d]. The fresh, as well as the salt springs in Bermuda, rise and fall with the ebb and flow of the tide[e].

Filtration of rain water.

It was formerly thought that rain water did not penetrate to any great depth in the earth, but was entirely absorbed by the first strata of the soil, and that it fell in too small a quantity to afford supplies, either to torrents or to rivers. But, if we observe the disposition of those strata which compose the surface of the globe, we shall find them all more or less inclined, overturned and cracked, from the numerous convulsions which they have undergone, or from the manner in which they have been formed. The rain water flows rapidly through the interstices and cracks of the upper strata, and does not stop until it arrives at the clayey part of the soils, which is the general termination of its filtering, and forms its natural reservoirs. Observation has also proved, that rain water filters down to very great depths. In the coal mines of Auvergne[f], it has been seen to penetrate as far as 250 feet. In Misnia, a town and district of Saxony, called also Meissen, rain water has been observed to distil in drops from the roof of a mine 1600 feet deep[g].

The snow and ice, it must be admitted, in some countries, produce a greater quantity of running water than the rain, the dews, and the aqueous vapours. But, in order to conceive how much the slow and gentle, but uninterrupted influence of these latter agents contribute to the formation of springs, we have only to consider Apulia and other peninsulas, almost destitute of running water, because their mountains do not constitute a mass sufficient, either from its elevation or its bulk, to attract and retain the aqueous va-

[c] Bergmann, ibid. 331.
[d] Lulof, Géog.-Physique, § 358.
[e] Norwood, Philosoph. Transactions abridged, ii. 298.
[f] Le Monnier, Observations d'Hist. Naturelle, p. 194.
[g] Muschenbroek, Institit. Phys. § 894.

pours of the atmosphere. On the same principle, that it is from the sea the atmosphere exhales its water in the gaseous form, it is easy to explain why the interior of many great continents, such as Africa and Asia, contain such barren deserts. If the two Americas are more abundantly watered, they owe it to the extent and elevation of their mountains, as well as to the continuity of their declivities.

Motion of running water.

The water which circulates on the surface of the globe has generally no other principle of motion than its own specific gravity, and the declivity of the earth. It is this declivity which carries it from mountain to mountain, from valley to valley, until it falls into the basin of the ocean.

Spouting springs.

The *spouting springs*, which sometimes form natural jets of water, follow the same rules of equilibrium as the others, except that the canals which furnish them with water come from great elevations, and with a rapid descent. Waters thus carried into a subterraneous reservoir, finding themselves closely confined, burst forth in consequence of the pressure, just like those water spouting fountains and works with which art embellishes our gardens. *Springs of boiling water*, which appear to accompany the volcanos, probably obey the same laws. A French naturalist, however, is of opinion, that the majestic phenomena of the spring called the Geyser, in Iceland, were produced by subterranean vapours, which, suddenly bursting forth, raise an immense body of water resembling the ancient crater of a volcano [h]. But it is more probable that this spring receives its waters from the neighbouring heights.

Intermitting or periodical fountains.

The *intermitting fountains*, particularly such as rise and fall at regular periods, so excited the wonder of the people, that they give them the name of *miraculous fountains*. The periodical fountain of Como in Italy, has been described by Pliny; it rises and falls every hour [i]. There is another in the town of Colmars, in Provence, which rises eight times in an hour. There is one at Fronzanches, in Lan-

[h] Delamétherie, Théorie de la Terre, iv. 309, (2d edit.)

[i] Pliny, l. ii. c. 103. Scheuchzer, Hydrograph. Helvetica, p. 126.

guedoc, the period of whose rising is each day fifty minutes later than the preceding day [k]. The *round fountain*, on the road from Pontarlier to Touillon, in Franche-Comté, rises with a boiling appearance. The *Bullerborn*, in the bishopric of Paderborn, in Westphalia, rises with great noise. Near Brest, there is a well 75 feet from the sea, which sinks with the flow and rises with the ebbing of the sea [l]. England furnishes many examples of these springs, one particularly near Torbay, in Devonshire, and one at Buxton, in Derbyshire. According to Gruner, there is one at Engstler, in the canton of Berne, which has a double intermission daily and annually [m]. But of all these kinds of springs, of which many more examples might be adduced, none exhibits a perfectly regular course. These springs are accounted for by supposing, that in the lands where they are situated, there are reservoirs and conducting pipes in the form of syphons. It is perhaps unnecessary to explain, that the liquid begins to flow through the syphon as soon as the surface of the liquid in which one end of the tube is placed on a level with the curvature of the two branches; and the flowing continues as long as the fluid keeps above the orifice of the branch or end inserted in it. The moment the orifice ceases to be immersed in the liquid, the flowing ceases, and it recommences as soon as the reservoir is filled to the level of the bending. With respect to the reservoirs which supply these fountains, drought, rain, and the melting of the snow, may so affect them, as to render their periodical return more or less regular. The connection subsisting between the greater or less humidity of the atmosphere, and the reservoirs of intermitting fountains, justifies to a certain degree the conjectures which are sometimes formed from the movements of these springs as to the nature of the approaching season, conjectures which have given to some of them the names of fountain of *dearth and plenty* [n].

Fountains of dearth and plenty.

[k] Astruc, Histoire Naturelle de Languedoc et de la Provence.

[l] Journal de Trévoux, 1728, Octobre.

[m] Scheuchzer, Iter Alpin. 26, ii. 404.

[n] Kant, Géographie-Physique, ii. part. 2. p. 221

It is natural to imagine, that many channels of water not finding any other suitable outlet, flow into subterraneous cavities, are absorbed by the earth, or discharge themselves below ground into the sea. We may thus explain the origin of those springs of fresh water that are to be seen spouting up even in the midst of the waves of the ocean. The water thrown up by volcanos, the sudden and terrible inundations of mines, the number of rivers which disappear, the mountains suddenly engulphed in the bosom of new lakes, all these facts combine in proving, that there are considerable subterraneous cavities, often filled with water. The necessity of supplying the scarcity of springs by digging wells, has procured us the knowledge of a fact still more interesting to physical geography. It appears, that there are lakes, or rather sheets of water, which extend under ground to considerable distances. Delamétherie relates [o], that in the province of Artois, near Aire, in digging wells, they always come to a clayey bed, which, being pierced, the water gushes out in large bubbles, and, rising up, forms springs which continually flow. In the country of Modena, we find every where, at the depth of 63 feet, a bed of clay five feet thick, and beneath it water which spouts out with much force [p]. In the interior of the country of Algiers, in the province of Wad-Reag, the inhabitants, after digging 200 fathoms deep, invariably meet with a stratum of slate, under which the water flows in such abundance, that they name it the *subterraneous sea* [q]. We may easily conceive that one bed of clay may have sunk down horizontally by drying, whilst another bed of clay may have been forced upwards. The fissure horizontally formed in this manner, may have served as a channel for the lakes or rivers which constitute these extensive subterraneous waters. Subterraneous waters.

The glaciers which crown the tops of the highest mountains, have a close connection and a common origin with Glaciers.

[o] Théorie de la Terre, tome iv. p. 563.
[p] Ramazzini, Topographia Mutinensis.
[q] Shaw, Voyage en Barbarie, tome i. p. 169.

springs. Snows accumulated for whole centuries, sink down and are compressed, and consolidated as much by evaporation, as by alternate thaws and frosts. Thus are formed immense caps which cover whole mountains or fields of frozen snow, which extend between the summits: The high vallies are filled at the same time with the snow which falls there, and with the icy waters which flow from the snowy summits. In fact, these flowings alone, joined to the avalanches, occasion those masses of pure ice, the branches of which extend even to the lower vallies. The latter masses of ice seem in some places to have continued increasing for a long series of years. They have, in Switzerland, filled up even whole valleys, buried villages, and shut up the pass between Le Valais and the Canton of Berne—but the diminutions on one side generally compensate for the increase of the other. A few warm seasons are sufficient to re-establish the equilibrium [1].

The scenes which these bodies of ice exhibit are as various as their extent. At one time a great mass of water, congealed at the period of a tempest, presents waves resembling those of a lake—at other times these inequalities disappear, and leave nothing to be beheld by the astonished traveller, but one immense mirror of polished ice. Here superb portals of crystal appear fallen into rivers, and brilliant spires broken to pieces—in other places, avalanches of snow glide over a field of ice and then stop, and, reflecting the rays of the sun, display the form of pyramids and obelisks unseen before. These glaciers are of essential service in furnishing to the continents slowly, and in an almost regular manner, waters which, without this congelation, would be precipitated with impetuosity from the height of the mountains, so as to overflow and devastate the countries which they ought to fertilize. For this beneficial effect, we are indebted to the intense cold which converts the waters into snow and ice, and holds them suspended on the sides of the mountains, to supply

[1] Sau sure, Voyages, Gruner, etc.

abundant and unfailing streams oozing from the bottom of these enormous masses, or from the bosom of their crystallized grottos.

Streams, rivers, torrents, and rivulets.

The effusion of springs, and the flowings of melted ice, form little currents, more or less gentle, which are termed *rivulets*. The water of great rains falls with more rapidity, and furrows the sides of the mountains by impetuous irregular *torrents*. The union of these currents forms *streams*, which, following the declivity of the ground, unite most frequently in a great canal which takes the name of *river*, and which conveys to the ocean the collected tribute of the earth.

Hydrographical basins.

The declivities (considered collectively, and as a whole,) from whence flow the streams and rivulets which discharge themselves into one particular river, are called the basin of that river, or its hydrographical region. It frequently happens, that the basins of two rivers almost touch. In America, the Cassiquiari, and some other rivers, actually unite the basin of the Oronoco, with that of the Amazon[s]. In Europe, the sources of the Duina, of the Niemen, and of the Borysthenes, nearly meet together in a marshy plain. Geology has been much employed in investigating the subject of *basins*; in general, the mineral beds and petrifactions of the same basin present a certain analogy; but, (according to the just observation of M. Desmarets,) it is also essential to distinguish with accuracy the hydrographical masses or groupes of mountains which furnish water to rivers that receive no supply from any other quarter. The knowledge of these masses is indispensable to assist us in explaining the nature of rivers. Calcareous soils produce waters of a very different nature from those which flow from the glaciers over sand or clay. The elevation of the springs determines the amount of the declivity, and this latter circumstance modifies the course of streams and rivers, rendering them rapid or gentle, regular or meandering.

Masses, or hydrographical plateaux.

[s] Condamine, Voyage de la Rivere des Amazons, p. 119. Hartsink, Humboldt, etc.

Beds of rivers.

The beds of rivers are the lowest parts of great chasms, formed by the same revolution which produced the mountains: The atmospheric waters have evidently brought down a portion of light soil which was adhering to the sides of the mountains; they may have formed by their sediments horizontal plains which occupy the bottom of certain valleys[t]; but never could a river by its own force alone have opened for itself a passage through solid rocks, similar to those which border the upper Rhine; it must at the first have found the outline of its course deeply marked out. Running waters unceasingly wear away their beds and banks in places where the declivity is very rapid; they hollow out and deepen their channels in mountains composed of rocks of a moderate hardness—they draw along stones, and form accumulations of them in the lower part of their course—and thus their beds are often gradually elevated in the plains, while they are deepened and depressed in the mountains; but these changes, though continually going on for thousands of years, could only give form to the banks of rivers; they in no wise created the banks themselves.

Declivity of rivers.

It is only the sloping of the land which can at first cause water to flow; but an impulse having been once communicated to the mass, the pressure alone of the water will keep it in motion, even if there were no declivity at all. Many great rivers in fact flow with an almost imperceptible declivity. The river of the Amazons has only ten feet and a half of declivity upon two hundred leagues of extent of water, which makes $\frac{1}{27}$ of an inch for every 1000 feet[u]. The Seine[x], between Valvins and Serves, has only one foot declivity out of 6600. The Loire has, between Pouilly and Briare, one foot in 7500; but between Briare and Orleans, only one foot in 13,596. In East Friezland, in

[t] Comp. Saussure, Voyages, §§ 618, 920. Delamétherie, § 1618. (For the action of rivers, see Bourguet, Lettres Philosophiques, 181. Voigt, Mémoires Minéralog. vol. iii. Mémoire sur la Formation des Vallées.)

[u] Condamine, l. c. p. 134.

[x] Picart, Traité du Nivellement, p. 152, etc. etc.

the United Provinces, two small neighbouring rivers have, the one $\frac{1}{8}$ of an inch, the other $\frac{1}{3}$ of declivity for every 1000 feet[y]. The Marwede, between Herdinxveld and Dort, falls an inch along 1,125 feet; but between Dort and the sea, only one inch along 9000 feet[z]. Even the most rapid rivers have less declivity than is commonly imagined. The Rhine between Schaffhausen and Strasburgh, has a fall of 4 feet in a mile; and of 2 feet between Strasburgh and Schenckenschantz. Hence we see the reason why one river may receive another almost as large as itself, without any considerable enlargement of its bed; the augmentation of its body only accelerates its course. Sometimes one river falling into another with great rapidity, and at a very acute angle, will force the former to retrace its course and return for a short space towards its source. This has happened more than once to the Rhone, near Geneva; the impetuous Arva, which descends from the mountains of Savoy, being swollen beyond its usual size, has made the more gentle waters of the Rhone flow back into the lake of Geneva; causing the wheels of the mills to revolve backwards[a].

Some rivers have no stream whatever, and the cause is easily discovered; the land having scarcely any declivity, does not impart a sufficiently strong impulse to their waters, which are constantly retarded, and finally absorbed by the sand. Sometimes these waters are evaporated by the heat of the sun, as is the case with the rivers of Arabia and Africa; but they more commonly flow into pools, marshes, or salt lakes. Confined rivers.

Rivers which descend from primitive mountains into the secondary lands, often forms *cascades* and *cataracts*. Such are the cataracts of the Nile, of the Ganges, and some other great rivers, which, according to Desmarets, evidently mark the limits of the ancient land. Cataracts are also Cataracts and cascades.

[y] Brahm. Principe d'Hydraulique, § 208. (en All.)

[z] Velson, Rivierkundige Verhandeling, p. 126, (in Dutch.) Compare the l'Hydraulique Générale de Wiebcking, (in German.)

[a] Saussure, Voyages, § 16.

formed by lakes: of this description are the celebrated falls of the Niagara; but the most picturesque falls are those of rapid rivers, bordered by trees and precipitous rocks. Sometimes we see a body of water, which, before it arrives at the bottom, is broken and dissipated into showers, like the Staubbach; sometimes it forms a watery arch, projected from a rampart of rock, under which the traveller may pass dry shod, as the "falling spring" of Virginia; in one place, in a granitic district, we see the Trollhetta, and the Rhine not far from its source, urge on their foaming billows amongst the pointed rocks; in another, amidst lands of calcareous formation, we see the Czettina and the Kerka, rolling down from terrace to terrace, and presenting sometimes a sheet, and sometimes a wall of water [b]. Some magnificent cascades have been formed, at least in part, by the hands of man: the cascades of Velino, near Terni, have been attributed to Pope Clement VIII. [c]; other cataracts, like those of Tunguska in Siberia [d], have gradually lost their elevation by the wearing away of the rocks, and have now only a rapid descent.

Height of cataracts.

The elevation of cataracts has generally been exaggerated: that of Tequendama, formed by the Rio de Bogota, in South America, estimated by Bouguer at 1500 feet, is, according to Humboldt, not quite 600 [e], and the highest fall ever known, that of Staubbach, instead of being 1100, as stated by some travellers, is only 900 according to trigonometrical measurement [f]. When the ground does not form a steep, and almost perpendicular bank, but only a very rapid declivity; and when at the same time the bed of the river is confined by rocks, the waters acquire by compression an astonishing force. Winterbotham relates,

[b] Herbinis, Dissertatio de Admirandis Mundi Cataractis, suprà et subterraneis. Amsterdam, 1678, in 4to. Voyages de Fortis, Carver, &c. &c.

[c] Opere di Monsignor Claudio Todeschi, (Rome, 1779,) vol. ii. p. 77.

[d] Isbraud Ides, Voyages au Nord, viii. 54, *sqq.* Muller, Sketch of Russian History, viii. 100—118, *sqq.* (in German.)

[e] Bouguer, Voyages au Perou, p. 91. Humboldt, Vues des Cordilliers, p. 22.

[f] Wyttenbach and Wolf, Storr, Travels in the Alps, i. 114—115, (in German.)

that the river of Connecticut, in the United States, at 40 leagues from its source, is so compressed by rocks, that it carries along on its surface, pieces of lead, as if they were so many corks; and that, notwithstanding the utmost efforts, it is impossible to insert an iron point in its waters: but this appears to be greatly exaggerated.

Periodical increase of rivers.

The periodical rise of the Nile was considered as a singular phenomenon, and one of the greatest mysteries of nature, until modern Europeans, by penetrating into the torrid zone, which was almost unknown to the ancients, discovered that this wonderful property belonged to a great many other rivers besides the Nile. It is now well known that in all the countries situated between the two tropics, it rains incessantly during a certain season of the year The period varies according to local circumstances, but it is sufficient to know, that the torrid zone, deprived in a great measure of the benefit of spow and glaciers, has this deficiency supplied by copious torrents of rain, pouring down incessantly upon the ground, which has been almost burnt with heat during the dry season: Then all the lakes and rivers swell and overflow their banks.

Increase of rivers parallel to the equator.

If a river, under the influence of these tropical rains, flows along a plain, in a direction parallel to the equator, its overflowing waters will spread with a certain degree of equality over the whole extent of its banks. Such, in a great measure, is the case with the Oronoco, in America, the Senegal, and probably the Niger in Africa.

Increase of rivers running from north to south, and *vice versa*.

If, on the contrary, such a river flows from a great elevation, from extensive mountains into deep plains and valleys; or, if its direction be perpendicular to the equator, that is, north and south, then, it is evident, that the action of the tropical rains will be extremely unequal in different parts of this river; for it is manifest that the surplus of water will be carried almost entirely towards the lower parts of the territory of the river. This is exactly what happens in the floods of the Nile. This river, as the ancients have said, and notwithstanding the assertions of Bruce, comes from the mountains of the Moon, which pro-

bably form a central and very elevated plateau, occupying the middle of Africa, and extending especially towards the east and south. In Asia, the rivers Siam and Cambodja, flow in almost the same latitudes as the Nile, but in a different direction: being from north to south. These two rivers have floods resembling those of the Nile; the Indus, the Ganges, and in general all the rivers which flow between the tropics, present this very phenomena, with variations arising from local circumstances. No river beyond the torrid zone is subject to regular periodical swellings; the overflowings which occur in the temperate zones depend solely on the melting of the snow in the spring, and on the quantity of rain which has fallen upon the mountains [g].

Rivers disappearing under ground.

The rivers which disappear under ground have excited the wonder both of ancients and moderns. The poets have sung of the Alpheus, which, according to them, passes from Peloponnesus into Sicily, beneath the Ionian Sea, to mingle its amorous waves with those of Arethusa. The ancients have mentioned a great number of rivers which lose themselves under ground, to reappear in a lower level [h]; but this phenomenon, which most frequently is closely connected with that of subterraneous caverns, has been examined in a rational and sober manner only by the moderns.

Causes of this phenomenon.

When a river is obstructed in its course by a bank of solid rocks, and finds beneath them a stratum of softer materials, its waters wear away the softer substance, and thus open up for themselves a subterraneous passage, more or less long. Such are the causes which have formed the *sinking of the Rhone*, between Seyssel and l'Ecluse [i]; the *bridge of Veja*, near Verona, the arch of which has an elevation of more than 114 feet [k]; and particularly the

[g] Varenius, Géographie Générale, ch. 16. prop. 20. Lulof, Géographie Physique, ii. 262, (in German.) Bergmann, i. 387, *sqq.* (in Swedish.)

[h] Pliny, ii. 103. Seneca Quest. Nat. iii. 26. Strabo, l. ix. 424.; xi. 518, edition Alm. Mœbius, Dissert de Fluviis, qui intercedunt et enascuntur.

[i] Annales des Voyages, iv. 81.

[k] *Z.* Betti, Descrizione d'un Maraviglioso ponte, 1766, Fortis in the Giornale d'Italia, vi. 241.

magnificent *Rockbridge* in Virginia, an astonishing vault uniting two mountains, separated by a ravine of 270 feet in depth, in which the *Cedar Creek* flows[l]. It is probable that the fall of a rock has formed these natural bridges, like those of Icononzo, in Mexico. In Louisiana, trees, or rather whole forests, have been observed to fall on a river, covering it nearly with vegetable earth; and thus giving rise to a natural bridge, which, for leagues, has hid the course of the river from view; finally, the Guadiana sees it waters scattered and filtered in the sandy and marshy grounds, from which they reissue in greater abundance. France affords very few examples of these disappearing rivers[m].

Mouth of rivers.

Rivers, in running into the sea, present a great variety of interesting phenomena; many form *sand banks*, as the Senegal and the Nile; others, like the Danube, rush with such force into the sea, that one can for a certain space distinguish the waters of the river from those of the sea. The water of the little river Syre in Norway, are discernible for a considerable distance, (some say for two leagues) in the sea[n]. It is only by a very large mouth, like those of the Loire, the Elbe, or the Plata, that a river can peacefully mingle with the sea. Rivers even of this nature, however, sometimes experience the superior influence of the sea, which repels their waters into their bed. Thus the Seine forms at its mouth a *bar* of considerable extent; and the Garonne, unable to discharge, with sufficient rapidity, the waters which it accumulates, in a kind of gulf between Bourdeaux and its mouth, exhibits this aquatic mountain, stopped by the flow of the tide rolling backwards, inundating the banks, and stopping vessels in their progress both up and down. This phenomenon, termed the "*Mascaret*," is only the collision of two bodies of water moving in opposite directions.

Mascaret.

[l] Jefferson's Notes upon Virginia.

[m] Guettard, Mém. de l'Academie, 1758.

[n] Pontoppidan, Histoire Naturelle de la Norwege, i. 115.

The most sublime phenomenon of this kind which presents itself, is that of the giant of rivers, the Orellana, called the river of the Amazons. Twice a-day it pours out its imprisoned waves into the bosom of the ocean. A liquid mountain is thus raised of the height of 180 feet; it frequently meets the flowing tide of the sea, and the shock of these two bodies of water is so dreadful, that it makes all the neighbouring islands tremble; the fishermen and navigators fly from it in the utmost terror. The next day, or the second day after every new or full moon, the time when the tides are highest, the river also seems to redouble its power and energy; its waters and those of the ocean rush against each other like the onset of two armies. The banks are inundated with their foaming waves; the rocks, drawn along like light vessels, dash against each other, almost upon the surface of the water which bears them on. Loud roarings echo from island to island. It has been said that the Genius of the River[3] and the God of the Ocean, contend in battle for the empire of the waves. The Indians call this phenomenon *Pororoca*. The researches which have been prosecuted as to the mass of water which roll along these rivers, as well as concerning the space over which they run in a given time, neither having terminated, nor being likely to terminate, in any general and positive result[o], we shall pass on to the theory of lakes.

Pororoca.

Lakes.

Extensive accumulations of water, surrounded on all sides by the land, and having no direct communication with the ocean, or with any sea, are called *lakes*. Lakes are of four distinct kinds.

Lakes absolutely isolated.

The *first class* comprehends those which have no issue, and which do not receive any running water. These *pools* are generally very small, and do not merit much attention. Some of these, as the Arendt, in Vieille Marche, are formed by the sinking down of the circumjacent lands[p]; others,

[o] Riccioli, Géog. Reform. x. c. 7. Lulof, Géog. Phy. § 338—392. Mariotte, Traité du Mouvement des eaux, &c. &c.

[p] Les Mémoires cités dans Kant, Geographie Physique, iii. part 1. p. 92.

like the lake Albano, near Rome, appear to be old craters of volcanos filled with water.

Lakes which receive no flowing water.

The *second class* consists of those lakes which have an outlet, but which do not receive any running water. Such a lake is formed by a spring, or rather by a multitude of springs, which, placed on a lower level in a kind of reservoir, are obliged to fill that before they find an outlet for their own waters. These lakes are nevertheless fed by little streams of water, almost invisible, which descend from the surrounding lands, or from subterraneous canals. Some great rivers have lakes of this kind for their source. These lakes are naturally situated on great elevations; there is one of this kind on *Mount Rotando*, in Corsica, which is 9294 feet above the level of the sea.

Lakes which receive and discharge their waters.

The *third class* of lakes is very numerous, consisting of all such as receive and discharge streams of water. Each of the lakes of this class may be looked upon as forming a basin for receiving the neighbouring waters; they have in general only one opening, which almost always takes its name from the principal river which flows into it. But it cannot, in strict propriety, be said that these rivers *traverse* the lakes, as their waters mingle with those of the basin over which they are diffused[a]. These lakes have often sources of their own, either near the borders, or in their bottom. There are four or five lakes of this class in North America, which, in point of extent, resemble seas, and which, notwithstanding, by the flow of a continual stream of fresh river water, preserve their clearness and sweetness.

Lakes without any outlet.

The *fourth class* of lakes present phenomena much more difficult to explain. We mean those lakes which receive streams of water, and often great rivers, without having any visible outlet. The most celebrated of these is the Caspian Sea; Asia contains a great many others besides. The Niger, if it does not touch the sea, most probably falls into a lake of this kind, and not into a marsh. South America

[a] Saussure, Voyages, § 10.

contains the lake Titicaca, which has no efflux, although it receives another very considerable one into it. In short, these lakes appear to belong to the interior of great continents; they are placed on elevated plains, which have no sensible declivity towards the sea, and which do not permit these collections of water to open for themselves a passage through which they may flow out. But why do these lakes, which are always receiving supplies of water, but have no outlet, why do they not overflow their banks? We may answer, that with respect to those which are situated in a hot climate, evaporation, as Halley observes, is sufficient to carry off their excess of water. It remains to be determined, whether the reasonings of this philosopher can with justness be applied to a climate so cold for example as that of the Caspian Sea.

Let us, in the first place, observe, that the quantity of water which the rivers pour into this basin, has been exaggerated: there are no other great rivers except the Wolga, the Iaik, and the Kur, which flow into it; the remainder consists only of small rivulets. We must add, that the whole of the eastern coast scarcely furnishes one rivulet to this extraordinary sea. And let us also remark, (for in physical geography every fact is worthy of attention,) that the Wolga, by no means a deep river, seems to be in part absorbed by the ground which borders its course; and it is this humidity which renders these lands so distinguished for their fertility, when compared with the neighbouring soil. Finally, were we determined to suppose that there is a disproportion between the extent of the Caspian Sea and its evaporation, on the one side, and the volume of water that it receives on the other, (which we are far from allowing,) we have still to take into account the absorption of its waters by the calcareous mountains which border it towards the south and south west. We know how porous and spongy land of this kind is. All accounts agree in describing the mountains to the south of the Caspian as being still more penetrated with moisture, and more abounding

in springs than those of Mingrelia, which proves either absorption, or (what is of more consequence,) a very strong evaporation. The insalubrity of the air near these lakes, is another circumstance which still farther confirms the opinion of Halley[r]. The physical phenomena, which certain lakes present, have always excited the astonishment of the multitude.

The *periodical lakes* are the most common. Those which are formed by excessive rains, and which are again dried up by the rays of the sun, by evaporation, or infiltration, appear to be scarcely worthy of our attention. In Europe these are nothing but pools, but between the tropics, these pools sometimes cover spaces of several hundred leagues in length and breadth. Such are the famous lakes of *Xarayes* and *Paria*, inscribed on maps of America, and expunged from them by turns; it is probable that Africa contains a great many of this description. If there exist now in the numerous cavities of the earth subterraneous lakes of this kind, and if these communicate with other lakes which are visible, it is easy to imagine that the waters of these last may sometimes entirely disappear, by sinking down into the basin of the subterraneous lakes in proportion as they dry up. This lower basin again filling itself anew, the waters issue from it to fill the superior basin. If, in a supposable series of subterraneous cavities, the last link of the chain happen to be a mass of subterraneous water, situated at an elevated level in the bosom of a mountain, the periodical return of the waters in the visible basin may be accompanied by a motion similar to that of the spouting fountains. It is by means of such hydraulic machinery that nature keeps up the wonders of the lake of Cirknitz in Illyria, and in many others of the same description. Periodical lakes.

The alleged regularity of these periodical returns, attributed amongst others to the lake of Kanten in Prussia, is not supported by authentic testimony. By comparing to- The periods are regular?

[r] Bergmann, Géographie Physique, i. § 88, ii. § 106.

gether the observations made since 1715, upon the Caspian sea, we are convinced that this great lake augments and diminishes from 30 to 35 feet, according to the abundance of snow and rain in the countries from which it receives its waters; but we see at the same time, that these changes follow no fixed period [s]. The lakes which are supplied with water by the melting of the snow, may even change their level in the course of the same day, according as the action of the sun has more or less effect upon the neighbouring mountains. It is on this principle, we conceive, that the *seiches*, or periodical risings and fallings of the lake of Geneva, should be explained [t].

Lakes which rise, which boil, &c.

The variations and motions of lakes, which do not depend upon an augmentation of quantity, present very complicated questions: That any lakes communicate under ground with the sea, and owe their regular tides to such communication, is much to be doubted. The equilibrium of the atmosphere, deranged by electricity, or by any other cause, may occasion water to rise up, by altering the pressure which retains it at its level. There is a bay in lake Huron where electric clouds continually remain, and no traveller has ever passed it without hearing thunder [u]. In Portugal there is a pool near Beja, in Alentejo, which, by its loud noise, indicates the approach of a storm [x]. Other lakes appear agitated by the disengagement of subterraneous gases, or by winds which blow in some cavern with which the lake communicates. Near Boleslaw, in Bohemia, a lake of unfathomable depth, sometimes in winter emits blasts of winds sufficiently strong to raise up in the air pieces of ice several quintals in weight [y]. Two considerable lakes, *Loch Lomond* in Scotland, and the *Welter* in Sweden,

[s] Rytchkow. Topography of Orenbourg, (in German,) i. 166, 167. Pallas, Travels in the South of Russia, i. 434. (in German.)

[t] Jallabert, Mémoires de l'Academie des Sciences de Paris, 1741, p. 32. Compare Saussure, §§ 20—25.

[u] Carver, Voyage dans l'interieur d'Amerique, etc.

[x] Burges, cité par Bergmann, Géog. Phys. § 99.

[y] Acta Erudita, 1682.

often experience during the serenest weather violent agitations. In the Murche of Brandebaurg, the pool of Krestin often commences in fine weather to boil up in whirlpools, so as to engulph the little boats of the fishermen[z]. Perhaps the decomposition of calcareous stones has an influence upon some of these phenomena.

In the general history of lakes, *floating islands* occupy a great space in the writings of some geographers. But when, on the one hand, we consider how many inaccessible marshes there are always floating in the water, and notwithstanding, covered with brushwood, and even trees; and on the other hand, when we consider those beds of vegetables, those immense forests that are found buried, and very recently buried, in turf pits, we may then easily form an idea of these *floating islands* which some geographers represent as wonders of nature. They are simply earth of the nature of a peat, but very light, sometimes only reeds and roots of trees interwoven together. After having been undermined by the waters, they detach themselves from the bank, and from their lightness and spongy consistency, joined to their inconsiderable thickness, they remain suspended and floating on the surface of the waters[a].

The delightful *Loch Lomand*, in Scotland, contains some of these floating islands, which are not very uncommon in Scotland or Ireland. A small lake in Artois, near Saint Omer, is covered with similar islands. The marshy lakes of Comacchio present a great number[b]. The most considerable that are mentioned, are those of the lake of Gerdau, in Prussia, which furnish pasturage for 100 head of cattle; and that of the lake of Kolk, in the country of Osnabruck, covered with beautiful elms[c].

There are some floating islands which appear and disappear alternately. The lake Ralang, in Smalande, a pro- Floating periodical islands.

[z] Bernouille, Archives des Voyages, i. 325.

[a] Pliny, Natural History, ii. c. 95.

[b] Girolamo Silvestri, Treatise on Floating Islands, ancient and modern, (in Italian.)

[c] Kant. Geographie-Physique, ii. part i. p. 111.

vince of Sweden, encloses a floating island, which, from 1696 to 1766 has shewn itself ten times, generally in the months of September and October [d]. It is 280 feet long, and 220 broad. There is an island similar to it in Ostrogothia.

Floating islands which have become stationary.

The floating islands may have an influence upon the formation of the globe. Those which Pliny and Seneca saw floating in the lakes of Bolsena, Bressanello and others, have become fixed. West Friezland has a subterraneous lake, which appears to have been covered with floating islands, that gradually united together, and ended in the formation of a solid crust [e].

Temperature of lakes.

The shade of thick forests, or high mountains, may prevent certain lakes, like Loch Winnoch in Scotland, from getting rid of the perpetual ice which covers them in whole or in part. Other lakes, always ruffled by the winds, or stirred by the rivers which they receive, and the springs which feed them, brave all the rigours of a cold climate. The most extraordinary phenomenon would be to see lakes freeze during summer; and this has been related of some in China; the cause of which has been sought for in the saline nature of the neighbouring ground, but the fact appears to have been insufficiently observed, or incorrectly recorded [f].

The *depth* of lakes varies infinitely, and cannot form a subject of general physical geography. We must be satisfied merely with contradicting the popular opinion, that there are lakes without a bottom. Those which have been considered as such owe this character solely to the existence of currents which carry along with them the lead attached to the sounding line. But we must not reckon as fabulous the accounts of lakes with double bottoms, which are said to be found in Jemptia or Jemptland, in Sweden and elsewhere [g]. It has been supposed, that a crust interwoven

[d] Bergmann, Géographie Physique, ii. 238.
[e] Annals of the Prussian Monarchy, 1799, p. 292, (in German.)
[f] Mémoire de l'Academie des Sciences, 1712
[g] Bergmann, § 93.

with roots, similar to the floating islands, may exist at the bottom of a lake, and by either rising or sinking, may make the depth vary in appearance.

Such are the principal observations we have to make upon the origin and motion of springs, rivers, and lakes. We are now to consider them with relation to their chemical nature. We have already remarked the property which water possesses of absorbing atmospheric air. It is estimated, that fresh water generally holds in solution $\frac{1}{30}$ of its weight of air. A certain time is necessary before it becomes saturated with salt, and all the elements of atmospheric air are not absorbed by water with equal readiness. Pure oxygen unites most easily with it: The good quality of fresh water consists in being completely saturated with oxygen, which must be frequently renewed by the running and agitation of the water. Its bad quality arises either from the alteration, or the superabundance of the oxygen; and each of these states announces the presence of a heterogeneous substance in water, capable of absorbing more oxygen, or of altering it. These heterogeneous substances are earthy salts, sulphur, lime, gravel, and mud. Chemical nature of waters.

These principles, completely established by modern chemistry, would lead us to believe that the influence of *local* exposure upon the nature of waters is as powerful as Hippocrates has represented it [h]. Waters exposed to the *rising sun*, says he, are limpid, inodorous, soft, and agreeable to drink, because the sun at its rising corrects them by dissipating the fogs of the morning which may have mingled with them. Waters lying towards the *setting sun* are destitute of this advantage, and are not limpid. Those which flow towards the *south*, and are exposed to hot winds, should be brackish, not very deep, and consequently hot in summer and cold in winter, and likely to enervate man, and to render him liable to several maladies. Lastly, waters having a *northern* exposure, should in general be cold, hard Influence of exposure upon water.

[h] Traité des Airs, des Eaux, et des Lieux, § 9, 20, 22, 25. Edit. de Coray.

and unpleasant, the use of them drains away the milk from women, and renders them barren. Such is the system of Hippocrates; but we ought not, with the blind admirers of that eminent physician, to extend its application too widely; for it is connected with his ideas upon the particular nature of winds, and these ideas contain only local truths, applicable to Greece and Asia Minor.

The waters of marshes. The waters of marshes, pools, and all those which stagnate under ground, are unwholesome; they dissolve azotic and hydrogen gases, arising from the decomposition of plants, insects, and fishes. The surrounding atmosphere is loaded with these noxious gases. They who live near marshes, and who drink the waters, lead a miserable life, never acquire strength, and prematurely feel all the infirmities of age.

In Salogne, (in France,) to go no farther in quest of an example, the stagnant humidity gives to the natives pale countenances, languishing eyes, and a weak voice[1].

Stagnant waters almost always absorb a great quantity of fixed air, or carbonic acid gas; for this gas is carried by its gravity towards the surface of the waters, and does not disengage itself.

Waters of hills and mountains. The *water of hills and mountains*, differs in its quality, according as it filters through banks of pure rock, of schist, of quartz, or of sand, from all which substances it can scarcely derive any property whatever;—or, as it flows over beds of *potter's earth*, which it neither draws along with it nor dissolves;—or, lastly, as it traverses ground which is calcareous, marly, gypseous, impregnated with magnesia, salt, or bitumen. Waters of the kind last mentioned are always very much mixed with heterogeneous substances, and for the greatest part of the year are hard, turbid, and unwholesome, at least if daily used. Hippocrates, Homer, and Plutarch, have long ago condemned the use of them[b]. Those waters which have clayey bottoms are the most com-

[1] Mémoire de la Société Royale de Médicine, 1776, p. 61—72.

[b] Hippocrates, l. c. §. 35. et le Commentaire de Coray, p. 107

mon; they unite those qualities which are essential to salubrity. Those which flow from the hard rock are still more pure and limpid, as they must undergo a process of filtration in wearing their way over a stony bed.

Waters of lakes.

The waters of *lakes* being derived from springs and rivers, partake of their different qualities. There are some lakes whose waters are extremely limpid, such as the lake of Geneva, and that of Wetter in Sweden; in the latter, a farthing may be perceived at the bottom of the lake at 120 feet depth; but the lakes whose waters are motionless, or saline, or bituminous, may be looked upon as equally unwholesome with those of marshes.

River water.

The *waters of rivers* contain some very heterogeneous elements, which seem necessarily to counteract each other; and it is, perhaps, as much owing to this reciprocal destruction of pernicious principles, as to continual motion, that river water is so generally serviceable to the wants of man, and supports the freshness and purity of the atmosphere wherever they flow. It often, however, forms a sediment of gravel and mud; and Hippocrates imagined, that, when used as a constant beverage, it produced, amongst other maladies, that of the stone [1].

Well water.

Well water, by remaining too long motionless, frequently acquires the bad qualities of stagnant waters.

Sea water.

Sea water acts as an emetic with us, but the inhabitants of the Island of Paques, in the Pacific Ocean, make it their common beverage.

Rain water.

Amongst the *atmospheric waters*, those composed of *rain* are the most wholesome on account of their softness, variety, and lightness. Hippocrates has justly observed the admirable process which nature employs in distilling the vapours raised from the earth by the action of the sun. These vapours are agitated and rolled about in all directions; their more earthy and turbid part separate, and, sinking by their own weight, form fogs; the remainder, more subtle and more light, is still more completely dissolved by the solar heat. It is of this remainder that

[1] Hippocrates, l. c. § 51, and et le Commentaire de Corny, 134.

the drops of rain are formed. But the first rain that falls after a long drought, in passing through the air, becomes charged with a great number of heterogeneous substances, and consequently gets very impure before it reaches the earth. The drops which follow are not subject to this inconvenience, but all rain water is liable to be soon corrupted.

Snow and ice water.

Snow and ice water have an origin very different from that of rain water. For snow and ice being formed by the absence of caloric, are consequently destitute of the more subtle parts of water. Water, therefore, in which these substances are dissolved, ought to be harder and heavier than that of rain. According to the most authentic accounts, the use of such water occasions swellings in the throat and other tumours [m].

Weight of waters.

The more water is mixed, the heavier it is. The following comparative statements are taken from Bergmann.

Distilled water weighs, - - -	1,000 .....
Spring water of the purest kind, -	1,001 to 1,005
River water, - - - - -	1,010 .....
Sea water, - - - - -	1,013 .....
Stagnant water, - - - -	1,102 .....

Mineral waters.

After having considered the qualities of common waters, we shall now make some observations upon *mineral waters*, that is to say, those waters which are combined with certain substances of the mineral kingdom, in a quantity sufficiently considerable to give them both taste and colour, properties, the absence of which, constitutes the essential and distinguishing characteristic of fresh water. These extraneous substances are either found in a state of very subtle mechanical division, or in that of a complete chemical solution. It is extremely difficult, even by the most careful analysis, to ascertain exactly the proportions in which they are combined [n]. They can, therefore, only be classed in a manner

[m] Fer ter, in Comment. de Reb. in Scient. Natural. et Medic. Gestis, xxiv. 221. Comp. ibid. Suppl. Decad. i. p. 453.

[n] Bergmann, Geog. Phy. §§ 73, 74, 57. Id. de Analysi aquarum in Opu c

far from being strict. Acids easily combine with water, but they as rapidly incorporate with any saline, earthy, or metallic substance, so that *acidulated* or *gaseous waters* scarcely ever contain free unmixed acid. The spring of Latera, 32 miles from Viterbo, and that of Selvena, 40 miles from Sienna, are produced as examples in which the free sulphuric acid is combined with water [o]. The lakes of Cherchiaio, of Castel Nuovo, and Monte Rotondo, also in Italy, present the free boracic acid [p]; but these are rare cases. Carbonic acid is met with, almost free, in the spring, called *Sawerling*, near Carlsbad in Bohemia [q]. The waters of this spring contain a quantity of the acid equal to their own volume; those of Selz or Seltzer, commonly contain only $\frac{4}{9}$; those of Pyrmont $\frac{5}{8}$; and, those of Spa $\frac{1}{4}$. Acidulated waters.

The acidulated *ferruginous* or chalybeate waters are the most common. We could reckon some hundreds in France and Germany. The acid in these is combined with ferruginous ochre: we also find magnesia, glauber salts, vegetable alkali, and muriate of soda, so that an imitation of them is very easy. Bergmann made some forty years ago for his own use, and that of his friends. The simple chalybeate waters, such as those at Forges and Aumale, are still more common. Those of Passy contain vitriol or sulphate of iron, and become black with astringent vegetables. *Bitter waters* are charged with sulphate of magnesia; such are those of Seidlitz and Epsom. The steppes of Siberia, to the north-east of the Caspian Sea, have a number of lakes of this kind. They almost form a chain from the Kuma and Bas Wolga, reaching beyond the Jenissei [r]. Near these pools there are some which contain alkali or carbonate of soda. In the plains of Hungary the same abundance Ferruginous waters.

Chimico-Phys. i. Hydrologie de Wallerius, (in Swedish;) de Monnet, (in French;) d'Otto, (in German.)

[o] Vandelli, de Thermis agri Patavini. Bergmann, i. 346.

[p] Lavoisier, Traité Elémentaire de Chimie, i. 266. Fourcroy, Elémens de Chimie, i. 500.

[q] Klaproth, Mém. de Chimie, i. 320.

[r] Georgi Description de la Russie, iii. 23—26.

of bitter waters is found. Perhaps this is a property common to all the basins of the ancient mediterranean seas.

Aluminous and soapy waters, &c.

Aluminous waters are not very numerous, we mention only those of Bath in England, of Crems and of Halle in Germany [s], and two or three in Russia. The *soapy* springs owe their properties to a small proportion of clay, which often floats on the surface like grease. The formation of the acidulated waters is one of those daily operations of nature, which has been subjected to the scrutiny of science. Running waters find, in the bosom of the earth, acidiferous substances, the acids of which either disengage themselves by their affinity to water, or by the fermentation which a stronger acid causes among the weaker acids. This chemical process is perpetually renewed. Lime, which contains two-fifths of its weight of carbonic acid, supplies, in abundance, mineral waters with this acid, which constitutes their general basis [t]. Sulphuric acid is disengaged from pyrites, which are very widely distributed over the earth [u]. Waters impregnated with this acid, will dissolve iron, lime, magnesia, in a word, almost all substances. Silex itself, which for a long time was considered as insoluble in water, is, however, found dissolved, not only in the boiling water in the neighbourhood of volcanos, as in the springs of the Geyser and Raikum in Iceland, but also in springs of a moderate temperature, and even in common water [x]. It was at first imagined, that silex became soluble only by its combination with the mineral alkali, as in the Geyser; but it has been proved that it is soluble by itself. Mineral waters do not remain in that state, in which a first chemical operation placed them; in their flowing or filtering, they sometimes meet with a salt, and sometimes an acid; and these different substances, by uniting, separating, or changing, according to their affinities with the basis of mineral

[s] Richter dans Crell. Annal. de Chimie, 1788, No. iv. p. 324.

[t] Bergmann, Géog. Physique, i. 370.

[u] Klaproth, Mém. de Chimie, i. 316.

[x] Bergmann, Dissertation sur la Source d'Upsala. Klaproth, Mém. de Chimie, i. 340, *sqq.* 319.

waters, communicate qualities to them, which serve to vary to infinity their chemical and medical nature.

We must not imagine that these combinations are all of them salubrious. Without mentioning those sulphurous or carbonic fumes which arise from several waters, it appears very certain that there are several springs impregnated with arsenical and mercurial vapours. But it is wisely and beneficially arranged, that it should be almost always under large masses of rock that these frightful laboratories are buried, in which nature sustains a poisonous character[y]. According to Bergmann, arsenic, before it can be dissolved, requires 14 or 15 times its own weight of hot, and 90 times of cold water,—a circumstance which, joined to the rare occurrence of this destructive mineral, renders arsenical springs extremely uncommon. Poisonous waters.

There are also *simple metallic waters*, that is to say, those in which minute particles of metal are suspended, and which, not being combined with the fluid, are gradually deposited. Besides the common cementatory waters, as they are termed, which yield iron and copper, some are mentioned which have formed a deposit of argentiferous lead in a mine of Konigsberg. The auriferous rivers do not even retain the particles in suspension; they roll along grains of gold detached from some rock. These waters are not mineral in the proper sense of the word. Metallic waters.

Salt waters, or, to use the modern term, *muriated* waters, are perhaps the most common of all; but they rarely exist in a state of perfect purity. They occur in abundance along the Carpathian and Uralian mountains, and in general in the zone comprised between the 50° and 30° parallels of northern latitude. More to the north they are hardly ever found; farther towards the south, crystallized salt abounds in certain regions, as in the great desert of Africa; but we find only a few salt springs there. It is equally in the temperate zone of the north that the *salt lakes* are Salt waters.

[y] Varenius, Géographie Generale, ch. 17. prop. 12

abundant. The central part of Asia has a vast number of them.

Their origin.

Whence comes that saline quality which generally characterizes stagnant lakes? Some say that the soil in the neighbourhood has been originally impregnated with salt. This no doubt is one way of removing the difficulty: it would, however, be no easy matter to point out the enormous banks of salt which this hypothesis necessarily requires. Others consider all these salt lakes as the remains of the ancient ocean, which, in order to substantiate our *theories of the earth*, must be supposed to have formerly covered the globe. But why should the ocean have particularly affected these regions? Why are not all the lakes left salt and brackish from the same cause? It is the opinion of very able and accurate observers, especially of Halley[a], that all the lakes which receive a great quantity of fresh water, and which are in a state of stagnation, must have a brackish or salt taste, from the corruption of their waters, and from the decomposition of animal and vegetable substances which the rivers carry thither. There is only one objection to which this opinion is liable. We may ask, why do not the saltness, and especially the bitterness of these lakes progressively augment? But is it not possible in some measure to unite these three opinions? We will grant that the ancient sea did cover those countries; and we will suppose it to have disappeared from the influence of absorption or evaporation, and not in consequence of any efflux either sudden or slow. We shall then say, that certain soils being more compact, more glutinous, more cold; in a word, soils constituted in a particular manner, would be able to retain in greater quantity the saline particles of the ancient sea, which were already crystallized; finally, the decomposition of fresh waters, and of animal or vegetable substances, so far as it goes, ought to produce salt. With respect to the question, why

[a] Philosophical Transactions.

the saltness does not increase, it would be wiser perhaps to acknowledge, that the causes of this circumstance are not known.

The heat which *sulphureous waters*, or those charged with hydrogen sulphurated gas generally experience, has been explained in different ways. Common opinion attributes this phenomenon to the decomposition and combustion of the pyrites over which the waters pass; but it may be just as possible, that beds of burning coal may act an important part here [a]. Whatever the cause may be, hot springs are certainly one of the most curious phenomena in physical geography: their heat rises sometimes to an astonishing degree. The spring of Krabland, in Iceland, mounts even to 103 degrees of the centigrade thermometer of Celsius. Warm sulphureous waters.

The most magnificent of these springs is the great *Geyser* in Iceland, which rises up in the form of a pyramid of water and foam, more than 100 feet high; and the *Strok*, in the vicinity of the Geyser, that spouts up like a stream of water from a pump, to a still greater height [b]. This polar island beholds rivulets of hot water laving its shores, which are girdled with floating ice.

There are some waters which are capable of taking fire without being hot. Sometimes they contain inflammable or hydrogen gas, disengaged from mines of iron, zinc, and tin, dissolved by the sulphuric and muriatic acids. Such are the fountains of Porretta-Nuova, Barigazo, and others; such is the rivulet near Bergerac, which can be set on fire with lighted straw [c]. Sometimes these waters are mixed with pitch, or bitumen, especially with naphta and rock oil, which in general float on the surface, and burn in the bosom of water; this is seen at Bakou, and in several places in Persia. The burning lake of Iceland appears to belong to the first class, and it is not improbable that it may have sometimes taken fire of itself. Persons de- Waters which are inflammable.

[a] Klaproth, Mém. de Chimie, i. 313.

[b] See afterwards the Description of Iceland.

[c] Memoires de l'Académie des Sciences de Paris, 1699 p. 26

serving of credit assert, that they have seen the *ignis fatuus* fluttering on the surface of the lake Wetter in Sweden.

Petrifying waters.

Incrusting waters ought to be carefully distinguished from those possessed of a *petrifying* property. These last, charged with siliceous particles extremely minute, penetrate the pores of wood and other substances, and substitute for the elements of these bodies, other crystallized elements arranged in the same manner. This property shews itself stronger than any where else in *Lough Neagh* in Ireland, and in some few springs[a]; but most waters possess it in a certain degree. The Danube and the Pregel petrify, in the course of some ages, the stakes which are planted in them.

Incrusting waters.

Incrusting waters act in a more evident manner, by depositing like a crust the earthy particles with which they are loaded. The spring of Guancavelica, which by depositing calcareous sediments, furnishes the rough stones of which the neighbouring towns are built; the beautiful alabaster formed by the baths of St. Philippe in Tuscany, and by a hot spring near Tours; the deposits, known under the name of *sugar-plums of Tivoli*; the magnificent basin which the springs of Carlsbad have constructed for themselves; and many more examples might be referred to, but it would be unnecessary and superfluous to illustrate so simple a fact. Let us rather observe, that this quality of incrustation, belonging more particularly to hot springs, is likewise found in several that are cold.

The ordinary deposits consist of calcareous tufa or sandstone. The Geyser deposits a siliceous tufa. These observations may suffice for the theory of the soft and mineral waters collected upon the surface of the solid earth. A more extensive scene now invites us, the immensity of the ocean.

[a] Bruckmann, Magasin de Hambourg, 156, iv. 503, etc.

BOOK XIV.

Continuation of the Theory of Geography. Of the Sea, and Sea water. Of Tides and Currents.

General views.

THE sea is one of the most important subjects of physical geography. The ocean, by its exhalations, which refresh and moisten the air, supports vegetable life, and furnishes the necessary supply to those valuable canals of running water, which, though constantly flowing, never become empty. Without the kindly influence of these vapours, which every moment escape from the surface of the sea, all the earth would languish like a desert; the drying up of the ocean, whether slow or rapid, would probably be sufficient to reduce all organized nature to a state of annihilation. That vast mass of water is equally useful for absorbing and decomposing a great quantity of noxious gas, and animal and vegetable remains. The ocean too, by affording increased facilities to commerce, secures the advantages of neighbourhood to nations which so many lofty mountains and so many rapid rivers seemed to have separated for ever from each other.

We have treated of the *varied appearances* of coasts which form the common boundaries of sea and land. As to the bottom of the basin of the sea, it seems to have inequalities similar to those which the surface of continents exhibits: if it were dried up, it would present mountains, valleys, and plains. It is, moreover, inhabited almost throughout its whole extent, by an immense quantity of testaceous animals, or covered with sand and gravel. It was thus that Donati found the bottom of the Adriatic sea; the bed of testaceous animals there, according to him, is several hun-

Bottom of the sea.

dred feet in thickness [a]. The celebrated diver Pesecola, whom the Emperor Frederic II. employed to descend into the strait of Messina, saw there with horror, enormous polypi attached to the rocks, the arms of which, being several yards long, were more than sufficient to strangle a man [b]. In a great many places, the madrepores form a kind of petrified forest, fixed at the bottom of the sea, and frequently too, this bottom plainly presents different layers of rocks and earth. The granite rises up in sharp pointed masses.

Near Marseilles, marble is dug up from a submarine quarry. There are also bituminous springs, and even springs of fresh water, that spout up from the depths of the ocean; and in the gulf of Spezia, a great spout or fountain of fresh water is seen to rise like a liquid hill [c]. Similar springs furnish the inhabitants of the town of Aradus with their ordinary beverage [d].

On the southern coast of Cuba, to the south-west of the port of Batabano, in the Bay of Xagua, at two or three miles from the land, springs of fresh water gush up with such force in the midst of the salt, that small boats cannot approach them with safety; the deeper you draw the water the fresher you find it [e]. It has been observed, that in the neighbourhood of steep coasts, the bottom of the sea also sinks down suddenly to a considerable depth, whilst near a low coast, and one of gentile declivity, it is only gradually that the sea deepens [f].

Depth of the sea.

There are some places in the sea where no bottom has yet been found. But we must not conclude that the sea is really bottomless; an idea, which, if not absurd, is at least

[a] Donati, Storia Naturale Marina del Adriatico. Marsigli, Histoire Physique de la Mer.

[b] Kircher, Mundus Subterraneus, l. ii. c. 15.

[c] Spallanzani, Journal de Physique, July, 1786.

[d] Strabo, Geog. l. xvi. p. 753, edit. Casaubon 2do. Comp. Pliny, Hist. Nat. v. 31. ii. 103.

[e] Humboldt, Tableaux de la Nature, i. 235.

Dampier, Voyage round the World, ii. 119. Pontoppidan, Natural History of Norway, i. 109, (in Danish.)

by no means conformable to the analogies of natural science. The mountains of continents seem to correspond with what are called the abysses of the sea; but now, the highest mountains do not rise to 20,000 feet. It is true, that they have been wasted down and lessened by the action of the elements; it may, therefore, be reasonably concluded, that the sea is not beyond 30,000 feet in depth; but it is impossible to find the bottom even at one-third of this depth with our little instruments. The greatest depth that has been tried to be measured, is that found in the northern ocean by Lord Mulgrave; he heaved a very heavy sounding lead, and gave out along with it cable rope to the length of of 4,680 feet, without finding the bottom.

Level of seas.

The level of seas is, generally speaking, the same every where. This arises from the equal pressure in every direction which the particles of a fluid exercise upon each other. The ocean considered as a whole, has then a spherical, or rather a spheroidical surface, which may be considered as the true surface of our planet. The only exception to this position, may perhaps be found in gulfs and inland seas, which have only a slight communication with the ocean. In these parts of the sea, the level of the water may sometimes be a little more elevated than in the ocean. It is alleged that the Dutch found the level of the gulf of the Zuyderzee considerably higher than the North Sea[a]. It appears more probable, that the Arabian Gulf is more elevated than the Mediterranean, and that in general, small portions of sea, open only to the east, have a higher level on account of the accumulation of the waters driven into these gulfs, as into an alley, without an outlet, by the general movement of the sea from east to west, a movement of which we shall hereafter speak. There are also mediterranean seas where the level of the waters change with the seasons. The Baltic and Black Sea swell in the spring from the abundance of waters which the rivers bring along with them. These two interior seas approach more

[a] Varenius, General Geography, p. 101, edit. of Newton.

nearly the nature of lakes, which have generally a higher level than the ocean.

Sea water contains, besides pure water, several extraneous substances, in proportions which vary in different places.

Chemical nature of sea water.

Muriatic, or marine acid, vitriolic, or sulphuric acid, fixed mineral alkali, magnesian, and sulphated lime, form in general the component parts. By boiling or by evaporation in the air, common salt is obtained, (muriate of soda,) which is preferred for salting meat, to the salt of springs. The saltness and bitterness of sea water, renders it disagreeable to the taste, and unfit for the use of man.

Saltness of the sea.

The saltness of the sea seems in general to be less towards the poles, than under the equator. There are, however, exceptions in certain countries, and generally in all gulfs which receive a great many rivers. The following observations upon this subject are from Bergmann[h].

Near Iceland, the sea contains of salt,		$\frac{1}{12}$ to $\frac{1}{16}$ of its weight.
Near the coasts of Norway, North Sea[i],		$\frac{1}{10}$ ... $\frac{1}{7}$ .....
In the Kattegat, near Warberg[k],		— ... $\frac{1}{18}$ .....
In the Baltic Sea,		— ... $\frac{1}{50}$ .....
In the gulf of Bothnia,		$\frac{1}{60}$ ... $\frac{1}{80}$ .....
In the North Sea,	Near Northumberland,	— ... $\frac{1}{26}$ .....
	Near the Thames,	— ... $\frac{1}{29}$ .....
	Upon the coast of Holland,	— ... $\frac{1}{32}$ .....
In the Irish Sea, near Cumberland,		— ... $\frac{1}{26}$ .....
In the English Channel,		— ... $\frac{1}{30}$ .....
In the Atlantic Sea,	Coasts of France,	— ... $\frac{1}{32}$ .....
	Coasts of Spain,	— ... $\frac{1}{24}$ .....
In the Mediterranean,	Near Castiglione,	— ... $\frac{1}{24}$ .....
	5 miles to the north of Malta,	— ... $\frac{1}{27}$ .....

Sea water is in several places less salt at the surface than at the bottom. In the straits of Constantinople, the proportion is as 72 to 62. In the Mediterranean, as 32 to 29. It has been found, says Bergmann, that in the Œresund, the water taken at the surface, and from the

[h] Physical Geog. i. 431. Comp. Ingenhousz, Experiments upon Vegetables, p. 284.

[i] Hierne, Tentam. Chem. ii. 178.

[k] Swedenbourg, Miscel. Observat. 103.

depth of 5 to 20 fathoms, was in proportion to melted snow water, as 10,047, 10,060, and 10,189 to 10,000. Water ought to be denser and heavier at a certain depth, and from the result of experiments, in which a pressure has been applied to it, equal to what it sustains 1,800 fathoms from the surface, it has been computed that at that depth it should be compressed $\frac{13}{1000}$ by its own weight. Sea water, by acquiring additional saltness seems, at a certain depth, to lose its bitterness; so, at least, it appears from the observations of Sparrmann, who took up a bottle of sea water from the depth of 60 fathoms, and found it had the taste of fresh water, in which common salt had been dissolved. According to chemical analysis, it had very little magnesia [l].

Variations of the saltness of sea water.

Sea water experiences great changes from the agitation of the waves, from the variations of seasons, and from the action of the currents. Near Walloë, in Norway, where there is a salt-pit, it has been remarked, that the sea water taken at the surface contains $\frac{1}{21}$ of its weight of salt at the moment the ice is detached, which extends 30 feet down; whilst the salt in every other season is in the proportion only of $\frac{1}{30}$. Upon the coasts of Cumberland, in England, a still stronger evaporation is experienced, as there is generally $\frac{1}{13}$ of salt in the sea water, which is sometimes reduced by excessive rains to $\frac{1}{30}$. Upon the coast of Malabar, the sea water sometimes becomes drinkable [m]. In the Sound, the waters change their weight and saltness with the winds and currents: when they come from the east, the water weighs only $\frac{47}{10000}$ more than melted snow; on the contrary, when they come from the west, it weighs $\frac{120}{10000}$. It is supposed that in Iceland the sea is more salt during the flow than the ebb of the tide, whilst in the Gulf of Bothnia, it is quite the contrary; for the inhabitants know by the progressive increase of the saltness during the ebb,

[l] Bergmann, dans la Magasin de Physique de Gotha, ii. cah. i. p. 99—101. (2d edit. German.)

[m] Duhamel, Philos. Burg. cité par Bergmann, i. 434.

the moment when the flow approaches. In this gulf, the saltness of the sea is in general greater towards the winter, and less towards the summer solstice, which unquestionably arises not only from the flowing of the rivers, but also from the melting of the ice [n].

Origin of the saltness of sea water.

It is easier to perceive the great advantages resulting from the saltness of sea water, than to discover its origin. Without this saltness, and without the agitation in which they are continually kept, the waters of the sea would become tainted, and would be infinitely less adapted for the motion of vessels, and probably it is to this that the inhabitants of the ocean owe their existence. But whence comes this saltness? Is it from beds of salt lying at the bottom of the sea? These beds themselves appear rather to consist of deposits which the sea has formed by precipitation. Does the saltness originate from the corruption of river water? It seems, in fact, that the fresh water which is discharged into close and stagnant lakes becomes corrupted, decomposed, and forms deposits of salt. Now the ocean may be considered as a great lake, the common reservoir of all terrestrial waters. But in this case, it is said, that the saltness should increase from day to day. Halley, who broached this opinion [o], wishes that experiments were made which, in future ages, might conduce to throw light on the subject. Several modern philosophers consider the sea as the residuum of a primitive fluid, which must have held in solution all the substances of which the globe is composed; that these sea waters having deposited all the earthy principles, both acid and metallic, with which they were impregnated, there remains in their residuum, (which is the present sea,) some of these elementary principles too intimately combined with water to escape from it; and with respect to the bitterness of sea waters, as it diminishes in proportion to the depth, it can arise solely from the great quantity of decomposed and putrifying animals and vege-

[n] Palmstruck, Officier Suédois, cité par Bergmann, l. c.
[o] Philosophical Transactions, No. 334.

table substances which float in the ocean, and which the running waters never cease to bring into it.

Various methods have been employed to render sea water drinkable. The only one which has succeeded is distillation; but it requires too much care, and too much fuel to be made use of frequently, or on a large scale. Even distillation does not divest sea water of all its bitterness, when it contains sal ammoniac. Thus mariners, though sailing in the midst of water, often see themselves exposed to all the horrors of dying of thirst when their stock of fresh water has been exhausted. But should they be fortunate enough to fall in with floating or fixed ice, pieces of it, when melted, afford them water which is fresh, although a little insipid [P]. Attempts to render sea water drinkable.

The *colour* of the sea varies very much in appearance, but it is generally of a deep bluish green, which becomes clearer towards the coasts. This apparent colour of the sea seems to arise entirely from the same causes which impart a blue shade to distant mountains, and which give the atmosphere its azure hue. The rays of blue light, being the most refrangible, pass in the greatest quantity through the aquatic fluid, which, from its density and depth, makes them undergo a strong refraction. Colour of sea water.

The other shades in the colour of sea waters, depend on causes which are local, and sometimes illusory. It is said that the Mediterranean Sea, in its upper part, has sometimes a purple tint. In the gulf of Guinea, the sea is white, and around the Maldive Islands black. The Vermeille, or Vermillion sea, near California, has received its name from the red colour which it often assumes. The same phenomenon was observed at the mouth of the river Plata, by Magellan, and also in other places.

It is not impossible that a great number of certain insects may, for some time, give a reddish or whitish tint to an

[P] See, amongst others, Forster's Observations made during his Voyages, p. 50—52. (in German.) Brehmar, Nouvelle Méthode de Distiller l'Eau de mer, dans Voigt, Magazin des Sciences Naturelles, vii. 417, *sqq.*

expanse of sea. The infusion of certain earthy or mineral substances, the nature of the soil, and other causes, may produce these appearances.

The green and yellow shades of the sea arise from marine vegetables. In some places, these vegetables have been observed to rise to the surface of the water, and cover it entirely, as between the Canary and Cape De Verd Islands, in the road or rade which the Dutch call *Kroos-zee*, and the Portuguese *Mare di Sargasso*. This marine vegetation presents, upon a large scale, phenomena similar to the *efflorescence upon lakes*. In the lakes, there are very thin masses covered with hair, which rise during the day to the surface of the water, and sink beneath it during the night.

Marine vegetation.

Light of the sea.

The *light*, or *sparkling of the sea*, is a magnificent and imposing spectacle. Sometimes the vessel, while ploughing her way through the billows, appears to mark out a furrow of fire; each stroke of the oar emits a light sometimes brilliant and dazzling, at other times tranquil and pearly. These moveable lights are grouped in endless varieties. Here thousands of luminous points, like little stars, appear floating on the surface; and then, multiplying together, form one vast sheet of light. There the scene becomes more tumultuous, the refulgent waves heave up, roll, and break in shining foam. At other times, we see large sparkling bodies resembling the forms of fishes, pursuing each other, disappearing, and bursting forth anew.

Phosphorescence of sea animals.

The explanation of this phenomenon has very much occupied the attention of philosophers. Valisneri, Rigaud, Dicquemare [q], have shewn, that, on a number of occasions, this light was produced by a little animal called the *glow worm of the sea*. This animal has a body extremely thin and transparent, is possessed of astonishing activity, and emits a dazzling and vivid light. The observations of

[q] Rigaud, Journal des Savans, 1770, Cahier, de Mai, Dicquemare, Journal de Physique, Octobre, 1775. Vianelli, Nuove Scoperti alle Luce Nocturne. Venise, 1746.

Griselini, of Godcheu, of Dagelet, and of Adanson[r], have proved that the sea contains other luminous animals, particularly scolopendræ, and polypi.

The *medusas* dart from their antennæ, or horns, a very strong light, similar to that of a candle, whilst their body remains in obscurity[s]. The *pennatula marina* throws out so much light, that it makes all the other fish caught in the same net quite discernible at night[t].

All the Zoophytes and the Mollusca seem to be phosphorescent in a greater or less degree. The observations of M. Péron[u], and Langsdorff[x], confirm this explanation of luminous phenomena in the sea, and it is the only one that can be admitted as general. It appears that this emission of phosphorus arises from the excited state of the vital spirits in these different animals, and that it is chiefly at the moment of amorous enjoyment that they cast forth so brilliant a light.

Fougeroux, Canton, Forster, and other accurate observers, while they agree with respect to the existence of glow worms, think that the light of the sea, when it is tranquil, and as it were united with the water, originates from the decomposition of vegetable and animal substances, collected together in it, and which, in putrifying, emit their phosphorus. Light of this description is chiefly observed in long calms, and after great heat[y]. The spawn of fish also possesses the power of emitting a certain light—it is perhaps to this cause that we owe those luminous ap- Phosphorus of putrified matters.

[r] Lalande, Letter, &c. dans le Journal des Savans, 1777. Griselini, Observations sur la Scolopendre Marine, &c. Journal de Physique, 1784, Janvier, &c.

[s] Forskal, dans Niebuhr, Voyage en Arabie, i. p. 7, (in German.)

[t] Philosophical Transactions, vol. liii. plate 19, fig. 1—4. Shaw, Spallanzani, &c.

[u] Péron, Voyages aux Terres Australes, i. 41. Comp. Annales du Muséum, ii. cahier 2.

[x] Langsdorff, dans Voigt, Magasin de Physique et d'Histoire Naturelle, x. 202.

[y] Forster, Observations, etc. p. 57-58. Id. dans Sparmann, Voyage au Cap, p. 5. Canton. Philosoph. Transact. vol. lix. p. 446. Fougeroux, sur la lumière que donne l'eau, etc. Mémoires de l'Acad. de Paris, 1767.

pearances in the Northern seas, which are called by the fishermen herring lights. This marine phosphoric light has been noticed to be strongest during a storm, which has given rise to the belief that the phenomena was produced by the friction of the marine currents. Upon this subject, we shall quote [z] a reflection of Newton's: "Do not all solids," says this great philosopher, "when they are heated beyond a certain degree, emit a portion of light—and is not this emission produced by the vibratory motion of their particles? And do not all the bodies which abound in earthy, and particularly sulphureous particles, throw forth light as often as these particles are sufficiently agitated? may not this agitation proceed from heat, friction, putrefaction, from vital motion, or from some other cause? It is thus that sea water in a strong tempest becomes luminous [a]."

The light which arises from living animalcules generally precedes storms, the approach of which they thus in some degree appear to foretell.

Temperature of the sea.

The temperature of the sea changes less suddenly and less easily than that of the atmosphere. Sea water is a bad conductor of heat. Besides, the visible solar rays cannot heat the bottom of the sea, as they only penetrate to 279, or, according to Bouguer, 678 (French) feet. Beyond that limit the sea receives no more light—but the heat perhaps penetrates a little farther. The temperature of the depths of the sea would appear then to follow that of the interior of the globe in different latitudes. But the experiments of M. Peron have proved, that the temperature of the sea at great depths diminishes in a constant progression, from which fact, however, we must not conclude that the bottom of the sea is actually congealed [b].

Marine ice.

Marine ice appears to be produced towards the poles, according as the saltness of the sea diminishes, and the rotatory motion of each point of the globe becomes less rapid.

[z] Bajon, Histoire Naturelle de Cayenne, vol. i.
[a] Newton's Optic, p. 114.
[b] Peron, Memoire lu à l'Institut.

As low as the 40th degree of latitude, large pieces of ice are seen floating upon the sea, having been detached from some more northern place, and carried along by the currents which flow from the pole to the equator. At 50 degrees, it is common to see the rivers, the lakes, and even the edges of the sea covered over with ice. At 60 degrees of northern latitude, the gulfs and the interior seas are often frozen over their whole surface; at 70 degrees, the floating fields of ice become more frequent and more enormous; and towards the 80 degree, we find the ice more frequently stationary; not because the sea is frozen down to its bottom, but because the ice then sticks together, and becomes immoveable from the vastness of the masses in which it is accumulated. All these phenomena are met with in the southern hemisphere, but in a more rapid progression, so that fields of ice occur at 70 degrees, and extensive floating islands of ice appear in great numbers, and are sometimes even stationary in this side of the 60th degree of latitude.

The islands of ice are often half a league long, and rise 160 feet above the water. These enormous masses, so dangerous to ships, are formed, it is said, by the accumulation of sheets of ice which glide the one over the other; but we should be inclined to believe, that in several cases the masses of ice are like crystals formed simultaneously, and as it were at one cast. Congelation is in truth nothing but crystallization, and the principle which determines it may, towards the poles, be exerted with a force beyond our conceptions.

The fields of ice are frequently of immense extent. Cook found a chain of them which joined Eastern Asia to North America. The appearance of these continents and islands of ice surpass all that the imagination can conceive. Here, we fancy that we behold mountains of pure crystal and valleys sown with diamonds. There, greyish towers with their resplendent points seem to rise above a rampart crowned with ice. The magnifying medium of a hazy atmosphere, renders this spectacle still more gigantic. He must have a heart of iron who dare penetrate into these in- Appearance of that ice.

hospitable seas; for, if the navigator has not to fear tempests, which are extremely rare in these latitudes, nor water spouts and hurricanes, which are there unknown, he will be assailed with other dangers much more capable of appalling the most intrepid minds. Sometimes huge bodies of ice, impelled along by the winds and the currents of the sea, dash against his frail vessel; and there is no rock so dangerous nor so difficult to avoid. Sometimes these floating mountains treacherously surround the navigator, and block up every outlet; his ship is arrested in her course, and becomes immoveable. In vain does the feeble axe endeavour to break these enormous masses, in vain do the sails invite the winds; the ship is as it were soldered into the ice, and the mariner, cut off from the world of living beings, remains fixed in a solitude of death. How frightful is the situation of those who, thus hemmed in by the ice, have no other resource left than to quit their vessel and walk over that consolidated crust of sea, which is every moment cracking and ready to sink under their feet! When almost dead with cold and hunger, they consider themselves fortunate should the floating piece of ice on which they sail cast them upon the shore of Siberia, or Nova Zembla. But there is generally very little hope of life for the wretched beings who suffer shipwreck in these dreadful regions. Either the icy waves engulph them, or they are devoured by the tyrant of this dreadful empire, the white bear; or, lastly, the intensity of the cold extinguishes the vital heat, their feet adhere to the ice, their blood no longer circulates in their veins, and the polar night becomes to them a night which is eternal.

Dangers of the navigator in the frozen seas.

An ingenious writer[c] has imagined, that the poles were each of them surrounded by a vast cupola of ice, so extensive as to produce by its daily melting, the phenomenon of tides, just as the melting of the snow in the Alps occasions periodical movements in certain lakes and fountains; but the phenomena of tides cannot be explained in this manner,

[c] Bernardin de Saint-Pierre, Etudes de la Nature.

and even the existence of two similar cupolas is very doubtful. As a certain agitation is necessary to produce ice, it may be supposed that congelation was more of a permanent character towards the 80th degree than at the pole itself. Some sudden squalls of wind, which navigators experience in these latitudes, and which come from the pole, appear to indicate successive changes in the state of this extreme point of the globe. It is, at any rate certain, that the melting of the polar ice contributes to form the currents which set from the pole to the equator.

The masses of ice do not diffuse so piercing a cold around them in the regions where they are found, as, when detached and melting, they are carried by the waves towards other parts of the ocean; for, as ice is formed only in consequence of the absence of heat or caloric, its melting is occasioned by a new combination with the caloric; which it absorbs with avidity from the surrounding air, and consequently renders it extremely cold.

Motions of the sea.

The water of the sea yields to the slightest impression— and although its density and weight combine to retain it in a constant equilibrium, it is agitated to a certain depth, by very rapid and varied motions. These motions may be classed according to the manner in which the particles move, and according to the nature of the agents which give rise to the motion.

Difference of direction distinguishes the *horizontal* motions from the *vertical*. In the first, the water flows along the surface of the globe; in the others, it retires from, and approaches to the centre of the earth. Horizontal motions may be *direct* or *recurved*, or even *circular*, &c. On the extent and duration of the motion depends the difference between *oscillations*, in which the whole mass of water is moved at once, and *undulations*, in which the motion is propagated from one part of the mass to the other.

We may distinguish three kinds of motions in the sea, considered in reference to the causes which produce them; the tides are *sidereal motions*, because they depend upon the influence of the heavenly bodies; general currents, and the

greatest number of particular currents, have their causes in the very element that is agitated by them; these then are *motions of the sea itself.* The third kind comprehends *atmospherical motions*, produced by the action of the winds. As to those violent oscillations which accompany earthquakes, and thus evince the ocean to be connected with volcanos, I should wish to call them *sea-quakes;* they deviate much from the series of ordinary motions.

Regions of the seas.

We may distinguish in the sea three regions or beds, one above the other, but without any constant limit; the first, agitated by the winds, is the *region of undulations*—this is immediately followed by the *region of currents;* and lastly comes the *immoveable region*, where the density of the particles from pressure, and from their adherence to the globe and from friction, prevents all motion.

Waves, &c.

The motions of the air produce corresponding motions on the surface of the water. Unequal and violent winds give rise to *waves* which tower aloft like foaming mountains, roll, rebound, and dash against each other: one moment they seem to bear on their surface the goddesses of the sea who come to sport in the dance; the next they are involved in the fury of the tempest, they appear to swell with rage, and present to the imagination the monsters of the deep contending in wrath. A strong, constant, and equal wind, produces long ridgy *waves*, which all rise as it were with the same front, push forward with uniform velocity, and precipitate themselves in regular succession on the shore. Sometimes the waves, suspended by a gust of wind, or arrested by a current, form a kind of liquid wall, to the imminent danger of the navigator.

Cause of undulations.

All these oscillations arise from a current of air, which, by dislodging a certain portion of the waters, has destroyed the equilibrium which every moment they endeavour to recover. These motions are similar to those of a pendulum; they affect only the surface of the waters. The divers assure us, that in the greatest tempest, calm water is found at the depth of 90 feet. Geometricians have attempted to subject these motions to calculation. "The rapidity of the

propagation of waves," says an eminent philosopher [d], "will be the same as that which a heavy body would acquire in descending from an heighth equal to the half of the depth of water in the channel. Consequently, if this depth is one foot, the velocity of the waves would be $5\frac{51}{1000}$ feet in a second, and if the depth is greater or less, the velocity of the waves will vary in the subduplicate ratio of the depths, provided that they are not too considerable."

We must distinguish the *waves* produced by the momentary action of the wind, and those which arise from the impulse communicated by a preceding wind, or by a current, or by any other cause. Navigators often experience this double oscillation, which contributes to augment the agitation of the vessel.

Tides. The tides are regular and periodical oscillations, which the seas of the terrestrial globe undergo from the attractions of the celestial bodies, principally those of the moon and sun [e].

Action of the moon. Let us first consider the single action of the moon upon the sea; suppose then that luminary in the plane of the equator. It is evident, that if the moon exerted upon all the particles of the sea an equal attraction, and parallel to the earth's centre of gravity, the entire system of the terrestrial spheroid, and of the waters which cover it, would be influenced by a common motion, and their relative equilibrium would not suffer any change. This equilibrium is disturbed only by the difference between the attractions which the moon exerts, and the inequality of their directions. Some parts of the globe are directly attracted by the moon, others only obliquely. The former are in conjunction with the moon; and a line drawn from the centre of the two planets would pass through their zenith. The latter are in

[d] Lagrange, Mécanique Analytique, p. 491.

[e] Bernouilli, Memoire couronné sur le flux et le reflux. Memoirs of Euler and Maclaurin, the latter under the title of Theory of Flux and Reflux, 1740. Lalande, Traité sur le Flux et Reflux, 1781. Laplace, Système du Monde. Idem, dans les Mémoires de l'Académie des Sciences, 1790.

quadrature with the moon, that is to say, a line drawn from the terrestrial centre to their zenith, would make an angle of 90 degrees with the line which joins the centres of the two planets. The attractive force acting obliquely is decomposed, on account of the obliquity of its angle of incidence; thus the parts in conjunction being more strongly attracted than those in quadrature, the weight of their particles is diminished. It is necessary then, to there being an equilibrium in all parts of the sea, that the waters should rise under the moon, in order that the excess of weight of the particles in quadrature, above those in conjunction, may be compensated by the greater heighth of the latter.

The waters, however, rise not only on the side where the attracting planet is, but also on the opposite side, because if the planet attracts the superior waters more than it attracts the centre of the earth, it also attracts this centre more than it attracts the inferior waters in the opposite hemisphere. These waters then will approach less towards the attracting planet, than the centre of the earth approaches to it. They will remain as far off from and behind the centre, as the superior waters advance from it on the side of the moon.

Two promontories, or eminences of water, will therefore be formed by the action of the moon upon the earth—one on the side towards the moon, the other on the side opposite to it, which gives the sea an appearance of an elongated spheroid, whose great axis will pass through the centre of the moon and of the earth. It is *high* tide under the moon, and in the opposite point at 180 degrees of distance; consequently, in the two intermediate points, or at 90 degrees distance from the moon, the tide will be *low*.

High and low tide.

The earth, by its rotatory motion, successively presents to the moon, in the space of 24 hours, all its meridians, which, consequently, are found by turns, and at an interval of six hours, sometimes under the moon, and sometimes at a distance of 90 degrees from it: Hence it follows, that during the time which passes between the departure of the moon from one meridian, and its return to the same meridian.

that is, in the space of a lunar day, which exceeds the solar day by about 50 minutes and a-half, the waters of the sea will ebb twice, and flow twice in every part of the earth, although in a manner almost insensible in those places which are distant from the path or orb of the moon.

The earth, in revolving upon its axis, carries along with it, to the eastward of the moon, the promontories, or the most elevated particles of water; these will still continue therefore to rise by the action of the moon; and although that action, already less direct, is diminishing in force every moment, yet it subsists, and continues to combat with the inertia and friction which retard the elevation. It is for this reason, that the elevation does not attain its *maximum* at the very moment of the moon's passing the meridian, but about three hours after.

A second cause tends to produce the same effect. The waters placed in quadrature, on the west of the moon, and carried towards conjunction with that planet, by the rotatory motion of the earth, will be continually accelerated during the quarter of the day, when they are in this position, and will move after the syzigies or conjunction, with the sum of these accelerations, and then meeting with particles continually more retarded than the earth, they will form two contrary currents, which will place the greatest elevation at about 45 degrees past the syzigies. For the like reason, the greatest depression of the water will not happen at the quadrature, but three hours after, and at 45 degrees from that point.

Action of the sun.

If we now imagine the sun to be in the plane of the equator, it is evident that, as its action is similar to that of the moon, it should excite in the ocean an agitation similar to the lunar tides. Thus the sea would ebb twice and flow twice during a solar day; but, on account of the immense distance from the sun, these solar tides will be much smaller than those which result from the action of the moon. According to Lalande, the influence of the moon is $2\frac{7}{15}$ times greater than that of the sun; Laplace considers it even triple.

On account of the inequality which exists between the solar and lunar days, the action of the sun will sometimes change the position of the lunar tides, and at other times will unite its influence with that of the moon. In the syzygies or conjunctions, the action of the moon concurs with that of the sun to raise the waters. This is the reason why the highest tides happen at new and full moon; or when the moon is in its first and third quarters. In the quadratures, the waters of the sea are depressed by the action of the sun, at the same point where the action of the moon raises them, and reciprocally. Thus the tides of the quadratures ought to be less. But the highest tide does not, and should not happen precisely on the day of the new and full moon, but two or three days after. The reason of this is, that the motion once acquired, is not all at once destroyed; it continues to augment the elevation of the waters, although the instantaneous action of the sun is in reality diminished

What we have already mentioned regards the position of the sun and moon in the equator. Let us now consider these heavenly bodies in their various declinations, and we shall see the elevation vary in the inverse ratio of the cube of the distance of the water.

Without entering into details, which would require mathematical demonstrations, we will only remark, that the proximity of the sun and moon seems to be the cause to which we must refer the extraordinary equinoctial tides, which happen most frequently; the one before the *vernal equinox*, and the other, *after the autumnal*, that is, both of them at the time when the sun, passing through the meridional signs, is nearest us. But this does not happen every year, because there are sometimes variations produced by the situation of the orbit of the moon, and by the distance of the syzygies from the equinoxes. The great inequalities of the depth of the sea, the situation of the coasts, their declivity under water, sometimes rapid, sometimes otherwise; the different breadth of the channels and straits; and, lastly, the winds and currents; all these local, and sometimes accidental circumstances, alter the progress

Great equinoctial tides.

of the tides,—make them deviate from that regularity which they would have maintained in an open sea,—augment the impetus of the flow upon the coasts of confined channels, and by causing the degree of friction to which the waters are exposed to vary, shorten or prolong the relative duration of high and low water. Thus we see in the islands of the South Sea, regular tides of only one or two feet elevation [1], whilst upon the western coasts of Europe, and upon the eastern coasts of Asia, the tides are extremely strong, and subject to many variations. It is affirmed, that the Island of Formosa, near China, experienced, in 1632, a tide which passed above the chain of mountains, which traverses the island; but it is rather difficult to give full credit to this phenomenon. Upon the coasts of France, which border the British Channel, the flux being confined in a basin, and at the same time repelled by the coasts of England, rises to an enormous height; at St. Maloes, even to 50 feet.

In the gulf of Hamburgh, the tide is sometimes the result of three combined forces, namely, one flux coming from the straits of Calais, another flux coming from the Orkney Islands, and turned towards the German ocean by the polar current, or by the very strong north west winds; lastly, (as I believe) the repulsion of the waters of the Elbe and other rivers. The ordinary tide at Hamburgh rises 6 feet 8 inches. The tide of the syzygies, that is, of the new and full moon, is 7 feet 3 inches. But when the wind blows with violence from the north-west, the tide rises to 18 feet, sometimes even to more than 20 feet. Hamburgh is 30 leagues from the mouth of the Elbe, and the tide makes these 30 leagues in 5 hours 23 minutes; when it arrives at the mouth of the river, it takes from three quarters of an hour to one hour and a quarter to force back or overcome the river current. The same current makes the flood tide at Hamburgh last only 4 hours 18 minutes; and the reflux or ebb-tide 8 hours 6 minutes. This example may serve to explain all the phenomena of the tide, when

[1] Forster, Observations during a Voyage round the World.

confined in a narrow channel, and acted upon by a current contrary to its direction.

In the torrid zone, the flood tides run from east to west with the motion of the stars. In the northern temperate zone, they come from the south; and in the southern zone, from the north: that is, both of the temperate zones are affected by the influence which the heavenly bodies have upon the torrid zone; the waters of which are more directly under their agency. To this theory there are exceptions, but they are entirely local. The frozen zone of the north has very few tides; its distance from the equator, the land which surrounds it, as well as the ice with which its seas are encumbered, all combine to destroy the effect of a sidereal attraction. We know nothing of the southern frozen zone.

Seas without tides.

If it be objected to this theory of lunar attraction, that there are gulfs as well as inland seas in which there are no tides, we may answer, that these phenomena are fresh proofs in favour of the hypothesis against which they are brought. In small collections of water, the moon acts at the same time upon every part; it diminishes the gravity of the whole mass. But there is little or no surrounding water which can come and accumulate with the body thus attracted and elevated; for this swelling owes its origin less to a vertical or perpendicular motion of the attracted waters, than to the lateral flowing in of the neighbouring waters, in consequence of their superior gravity. This is the reason why the Mediterranean has only very small tides, which seem to be formed chiefly in the part extending to the east of the island of Malta, and to proceed northwards into the gulf of Venice.

Tides in gulfs.

The ocean communicates the effect of its tides to the gulfs and inland seas which have their entrances turned towards the cardinal points whence the tide comes. The Baltic and Mediterranean are not in this situation. But Hudson's and Baffin's Bays are, and there the tides are sensibly felt. The gulf of Arabia is also a striking example.

Maritime currents.

Let us now proceed to the consideration of the *motion*

of the ocean itself, that is, of general and particular *currents*. It is remarked, particularly between the tropics, and as far as 30 degrees of north and south latitude, that there is a continual motion in the waters of the ocean, which carries them from east to west in a direction similar to that of the *trade winds*, but contrary to that of the rotation of the globe[g]. Navigators, in order to go from Europe to America, are obliged to descend to the latitude of the Canary Islands, in order to catch the current, which carries them with rapidity to the west. They observe the same rule in going from America to Asia by the Pacific Ocean. We might imagine that they do this on account of the trade winds; but they assure us, that the action of the atmospheric current is very easily distinguished from that of the marine current. Of this they are convinced, because the vessel makes more way than it could do with the assistance of the wind alone. This fact is likewise proved by the direction in which bodies are observed floating on the surface of the waters; and in many of the straits, these currents are at times productive of effects extremely violent.

A second motion impels the sea from the poles towards the equator. It has also its corresponding motion in the atmosphere. The most decisive evidence of this motion, is deduced from the direction of the floating pieces of ice, which invariably proceed from the poles towards the equator.

The origin of these two motions appears to depend upon the sun, and the rotation of the globe. The motion which carries the polar waters towards the equator, (and which I shall designate by the names of *northern and southern polar currents*,) is explained in the following manner: Every day the solar rays dissolve an enormous quantity of ice; Polar currents.

[g] Kircher, Mund. Subterran. tom. i. lib. 3. sect. 1. Riccioli, Geographia Reformata, x. 3. §§. Fournier, Hydrographie, lib. ix. c. 22. Varenius, Géogr. Générale, ch. xiv. prop. 7, *sqq.* Pownal, Hydraulic and Nautical Observations, in the Atlantic Ocean, London, 1787. Franklin, Maritime Observations, in the Transactions of the American Society of Philadelphia, vol. ii. p. 315, *sqq.* Fleurieu, dans le Voyage de Marchand. Dampier, Forster, &c.

thus the polar seas have always a superabundance of water, which they endeavour to discharge. As the water under the equator has a less specific gravity, and as, moreover, the evaporation, which is very powerful under the torrid zone, absorbs a great part of it, it is necessary that the neighbouring waters should flow towards the equator in order to re-establish the equilibrium. This motion is propagated from one aquatic region to another; and thus, every moment, the circumpolar waters are impelled towards the equator.

Equatorial currents.

The motion from east to west, (which may be called a *tropical* or *equatorial current*,) appears to be the result of more complicated combinations. The trade winds, far from being the only cause of the general motion of the sea, may perhaps be rather the effect of it, at least in part. The sun and the moon in advancing every day to the west, relatively to a fixed point taken upon the earth, ought, according to Buffon, to draw the mass of waters on towards the west. This circumstance retards the daily tides, so that the flood-tide may be considered as a swelling of the sea, which makes the tour of the globe in 24 hours, 19 minutes, in retreating each day towards the west; whence, it may be concluded, that there ought to be an habitual tendency of the waters towards the west. This explanation is not sufficient for these phenomena: the following appears to us the most plausible.

Cause of the equatorial current.

The action of the sun, and the terrestrial rotation constantly diminish the gravity of the equatorial waters, and evaporation draws off a quantity infinitely greater than the rivers can supply. The waters of the seas more distant from the equator, are therefore impelled to fill up this vacant space; and thence arise the two polar currents. Now these waters, which come from the colder zones, (particularly in the great ocean, where the transition from one climate to another is more rapid,) these waters, I observe, have a considerably greater weight than those which they come to replace. But the most essential circumstance is, that they possess a rotatory motion infinitely slower than

the waters in the torrid zone; but these polar waters, from the force of inertia, do not at once lose the degree of motion which they first acquired. They cannot then follow the rotation of the globe; heavy and motionless in themselves, they have suddenly fallen into the sphere of the most rapid mobility; and preserve for some moments their primitive character. But the solid part of the globe moving with velocity to the east, leaves the waters always a little behind. Hence they *seem* to move towards the west with a rapidity proportioned to the superior velocity with which the solid parts of the earth really move towards the east; and thus the waters not readily conforming to the rotatory motion of the earth, retire from the western coasts of the continent, or rather the eastern coasts advance upon them.

Hence it appears that this great and wonderful motion is only a vast and calm oscillation, depending solely upon the equilibrium of the ocean. But when so powerful an oscillation meets with narrow straits, with obstacles which impede and divert, without stopping its regular course, it then changes into a current, which is violent and often very dangerous.

Let us now endeavour to explain, upon rational principles, the various modifications which the motion, *peculiar to the sea itself*, undergoes.

Currents of the great Eastern Ocean.

The Pacific Ocean, by its general motion, retreats from the coasts of America, and flows from east to west; and this motion is very powerful in the vast and uninterrupted extent of that sea. Near Cape Corrientes, in Peru, the sea appears to flow from the land, by this single cause. Ships are carried with rapidity from the port of Acapulco in Mexico, to the Philippine Islands[h]. But in order to return, they are obliged to go to the north of the tropics, to seek the polar current, and the variable winds. On the other side, the south polar current finding no land to im-

[h] See, in the course of this work, Description of South America, New Holland, New Guinea, and the Philippine Islands, &c.

pede it, carries along with it the polar ice even to latitudes where the motion of the tropical current begins to be felt. This is the reason why, in the southern hemisphere, floating pieces of ice are met with at 50, and even at 40 degrees.

Current of the Strait of Bass.

The Pacific Ocean, in its motion towards the west, is impeded by an immense archipelago of flats, islands, submarine mountains, and even lands of considerable extent; it penetrates into this labyrinth, and there forms one current after another. The direction which the principal of these currents observe, is conformable to the general motion towards the west. But, as might be expected, the inequalities of the basin of the sea, the coasts, and the chains of submarine mountains, sometimes turn these currents towards the north or south. We may easily conceive, that a strong repercussion of the waters of the ocean, in consequence of their meeting with a large mass of land, (as New South Wales,) may even produce a counter current, which will return towards the east, and which, by breaking, will also produce other currents differently directed. Here then is the origin of these currents, so adverse and dangerous, which Cook and La Perouse mention in their voyages.

The principal current, setting towards the west, still acts with force in the recently discovered strait, which separates New Holland from Van Diemen's Land; this is the current which bore away Captain Flinders, and which hindered so many ancient navigators from entering into that strait, because they approached it in a direction contrary to that of the sea[1]. The same current flows through the channel which separates New Holland from New Guinea; but here, from the innumerable inequalities which it meets with, it is subdivided into several currents, of varied and inconstant direction.

Current of the Gulf of Bengal.

Let us now enter upon the consideration of the Indian Seas. There we shall find the celebrated perpetual current, which runs along from New Holland, and from the

[1] Flinders, Observations during his Voyage to the Strait of Bass. London 1811. Compare the Voyage of Entrecasteaux, i. p 10.

Island of Sumatra, always to the north, as far as the bottom of the Gulf of Bengal. This current arises from the pressure of the polar currents upon the large opening which the Indian Sea presents to the south. That sea is bordered towards the north by a continent; the equatorial current, which is formed there, is therefore only feeble, or altogether ceases, as there is no mass of cold water passing from the north. On the other side, the Pacific Ocean cannot carry its impetus thither; it is broken and dispersed in the labyrinth of islands. Thus the influence of the southern polar streams predominates without a rival, and without an obstacle in the Indian Sea; and these produce that perpetual current which sets towards the Gulf of Bengal, upon a line more and more inclined towards the north west, or following the conformation of the coasts [k].

The action of the general motion of the ocean, at first weak in the Indian Sea, as we have already mentioned, augments by degrees, till it gains the ascendancy. It is easy to conceive that a general impulse which acts in a vast fluid, and which influences all its particles, ought to increase according as that fluid extends in the direction of the moving power. One part of the sea then reacts upon the other, and the sum of these repeated effects becomes in time immense. These principles show why, towards the Island of Java, the natural motion of the sea is changed by the northern current [l], of which we have already spoken, and why this same motion towards the west is found in the neighbourhood of Ceylon, and the Maldivia Islands. But a new local circumstance again makes this motion decline from its natural direction. A chain of islands and shallows extends from Cape Comorin, in the peninsula of India, to the northern point of Madagascar. The principal current being interrupted by these obstacles, turns to-

Different currents of the Indian Seas.

[k] Varenius, Géog. Générale, ch. xiv. prop. 24. Voyages de Gentil, de Macartney, and de Marchand, &c.

[l] We say a Northern Current, or a Southern Current, to designate a current with such a direction.

wards the south-west; and, in maintaining that direction, glides along that chain of mountains, some of them submarine, others on the shore. Having passed Madagascar, it turns towards Africa, dashes against that continent, and sweeps with great violence the coasts of Natal, (*Terre Natal*) in Africa; at the point where the coast of Africa, turning towards the west, ceases to present an obstacle to the progress of the water, the current loses all its impetuosity, and mingles in the general motion of the Ethiopian Ocean [m].

Current of the Natal coast.

We have said, that towards the Maldivia Islands, the principal current, or great mass of water, turns to the south-west; but the more superficial currents, and consequently the most variable, continue their course from the east to the west, that is, towards the Gulf of Arabia, and the coasts of Zanguebar. These are the currents which, setting towards the south-west, render the Mozambique Channel so difficult to navigate, and which have given the name it bears to Cape *Corrientes*, upon the coast of Inhambane. They reunite at the bottom of this Cape with the perpetual current.

Let us remark here, that in general the currents which do not extend to a great depth under the level of the waters, are liable to change with the winds, particularly when they blow for a long time with an equal and constant force, as the *Monsoons* do. These are the winds which give by turns entirely opposite directions to the currents which prevail from the Maldivia Islands to Arabia and Zanguebar. The shallows and rocks with which these parts are strewed, equally contribute to produce the same effect.

Currents upon the eastern coast of Asia.

The northern current which runs along Nova Zembla, and the Island of Sumatra, impels one of its branches through the strait of Sunda. This current, according to some authors, is the same that predominates in the Chinese Seas, and which La Perouse found to be of such strength

[m] Varenius, Géographie Générale, ch. xiv. prop. 25.

in the sea of Japan, and in the channel of Tartary[n]. But after comparing together the accounts of different navigators, it appears to us that these currents not only vary with the Monsoons, but that no connection subsists between them. All the southern and northern currents that we observe along the eastern coasts of the continents, are only necessary continuations of the general motion of the ocean towards the west; the waters, impelled by this motion towards the eastern coasts of the two continents, and finding no outlet, must with much force, flow back along the coasts in a southern or northern direction, as local circumstances determine them. In Behring's Straits, the polar current, which brings the ice from the polar seas to the environs of Kamtchatka, is distinctly felt.

Currents of the Western Ocean.

Let us go on to the currents of the Western Ocean. The form of the basin, whose length is much greater than its breadth, is what in a great measure determines these currents. The first current which presents itself to our notice, is that which carries forward the waters from the Ethiopian Ocean, along the coasts of Brazil, and through the Strait of Magellan, into the Pacific Ocean. This course is conformable to the general progress of the ocean. It would appear from the voyages of Marchand and Ingraham, that between Terra del Fuego, the New Georgia of the south, and the Sandwich Islands, (or the *Thule Australis* of Cook,) there are several opposite currents, but our knowledge of them is far from being accurate.

Current of Cape St. Augustin.

The most celebrated perpetual current of the Atlantic Ocean is that which commences on this side of Cape St. Augustin, in Brazil, and extends towards the eastern coasts of America. It is extremely rapid, and is felt in all the extent of sea over which the Antilles are scattered. This current is only the result of the general motion of the Atlantic Sea towards the west; it prevails between the

[n] Voyage de La Pérouse. See also, the articles of Japan, of Corea, of the Land Yeso, &c.

30th degree of northern, and the 10th of southern latitude, and begins at 20 or 30 leagues from the coasts of Africa. This is the reason why European vessels, in order to profit by this current, and the trade winds, proceed to the Canary Islands before they attempt to traverse the ocean.

Current of the gulf of Guinea.

Upon the coasts of Africa, within the limits pointed out above, there exists a current directly contrary to the preceding; which is neither less rapid nor less steady. Ships, if they approach too near these coasts, are drawn into the Gulf of Guinea, and with great difficulty get out of it. No adequate cause can be assigned for this singular current. Some authors imagine, that there are two currents in the Atlantic ocean, one at the surface, the other at the bottom; and that it is this latter which brings the waters towards Africa; but such an explanation is inadmissible, from the well known fact of the *general* motion of the sea, which is not superficial, but which pervades the whole of the mass. It is more probable that the current in question comes from the Straits of Gibraltar, along the coasts of Africa only, where the waters have not acquired all the velocity of the general motion; but we can affirm nothing with certainty on the subject.

Current of the Gulf of Mexico.

A third very celebrated current is that by which the waters of the Atlantic are carried violently into the Gulf of Mexico, and, discharging themselves through the *channel of Bahama*, run with inconceivable rapidity towards the north, or rather the north-east. It follows the coasts of the United States, becomes larger, and at the same time weaker, and extends, according to some navigators, as far as the coasts of Scotland and Norway. It is easily known by the beautiful blue colour of its waters.

Currents of the Frozen Sea.

The polar currents of the north exhibit very remarkable effects: it is they which bring upon the coasts of Iceland such an enormous quantity of ice, that all the northern gulfs of that country are filled with it to the very bottom, though they are often 500 feet in depth. The ice is sometimes raised up so as to form mountains. Some years no

ice, but immense collections of floating wood, particularly pines and firs, are cast ashore. It is in the semicircular hollow of the northern coast of Iceland that the wood and ices are accumulated. It is evident, that it is one and the same cause which brings them thither; and as it is impossible that great trees can be produced under the pole itself, the wood can come only from Siberia or North America. Floating wood.

The phenomenon of these floating forests, which are only found in the circumpolar seas of the north, has very much engaged the attention of geographers, and it is not yet perfectly explained. It is believed, that the wood is drifted partly from the Gulf of Mexico, by the current of Bahama, because specimens of timber have been occasionally seen, which grows only in Mexico and Brazil. These kinds however are in small quantities. Siberia and the unknown northern coast of America, contribute probably much greater portions[o].

It is very probable, that there may be in the same place a double local current, the one above, near the surface of the water, the other at the bottom. Several facts seem to prove this hypothesis, which was first proposed by the celebrated Halley. In the sea round the Antilles, there are some places where a vessel may moor itself in the midst of a current, by dropping to a certain known depth, a cable to which is attached a sounding lead. At that depth, there must unquestionably be a current contrary to that which is at the surface of the water; the stationary and quiet situation of the vessel arises from the equality of the two forces which act, the one upon the ship, and the other upon the cable with the sounding lead [p]. Similar circumstances have been observed in the Sound. There is reason to believe that the Mediterranean discharges its waters by an inferior or concealed current. A difference of density in the beds of water, a great rapidity of motion, and the coherence of Double currents.

[o] See for a more detailed opinion, the article Iceland, of this work.

[p] Observations of Dr. Stubbs, in the Philosophical Transactions, No. 97

fluid particles, are plausible reasons in favour of this hypothesis of double currents.

Opposite currents.

It is more easy to prove and explain the existence of opposite currents which pass along by the side of each other. In the Kattegat, a northern current proceeds from the Baltic along the coasts of Sweden, and another, a southern current, enters into the Baltic along the coasts of Jutland. In the North Sea there is a north current, which comes from the Pas-de-Calais, or that part which separates the English channel from the North Sea, and a south current which goes from the Orkneys along the British coast. The great rivers, while discharging themselves, occasion currents at their mouth often contrary to those of the sea. It would be superfluous to produce any examples of this.

Eddies of water.

When two currents of a more or less contrary direction, and of equal force, meet in a narrow passage, they both turn as it were upon a centre, which is sometimes spiral until they unite, or one of the two escapes. This is what is termed a *whirlpool* or *eddy*. The most celebrated are, the *Euripus*, near the Island of Euboea, *Charybdis*, in the straits of Sicily, and the *Malstræm*, in the north of Norway. These eddies sometimes augment their force by means of two contrary high tides, or by the action of the winds; they draw vessels along, and dash them against the rocks, or engulf them in the eddies, the wrecks not appearing till some time afterwards. Upon this simple ground, very marvellous fables have been invented, and mention has been made of gulfs at the bottom of the sea, and subterraneous rivers, and other things, the existence of which is quite imaginary.

Whirlpools.

Depth and quickness of currents.

The depth of currents is a physical problem very difficult to solve. The perpetual currents, however, from their regularity, and from their extremely strong action, even in the greatest calm, sufficiently indicate that they have a considerable depth. Their rapidity is no better known. It is independent of winds and undulations. But which of these two forces is to be distinguished as that which, acting on

the surface is more sensibly felt by navigators? There are many other questions impossible to solve that might be proposed on the subject of the ocean,—the cradle of the universe, and perhaps its grave.

Note. The facts recently brought to light respecting the action of the ship itself on the compass, afford reason to believe that some of the currents mentioned by navigators are imaginary. The existence of these currents has been inferred in many cases from the difference between the true course of a ship as ascertained by observation, and her apparent course as shewn by the compass. This difference, however, is explained in a satisfactory manner by the deflection of the needle from the magnetic north, by the action of the mass of the ship upon it; in consequence of which a ship's apparent course is often found to differ from her true, by one or even two points. The errors in reckoning which this produced, as mariners were long ignorant of their cause, were often ascribed to currents. See *Bain on the Variation of the Compass*, Edinburgh, 1817.

BOOK XV.

Continuation of the Theory of Geography. Of the Fluid which surrounds the Globe, or the Atmosphere. Of Meteors.

HAVING gratified our curiosity with contemplating the wonders of the earth, we proceed to the consideration of the vast assemblage of fluids with which it is surrounded, and which may be said to constitute an integral part of the globe itself. This celestial ocean, which is called the atmosphere, that is to say, the sphere of vapours, forms the subject of our present researches.

General views.

The atmosphere is the grand laboratory of nature, in which the various gases exhaled from our globe are collected together, and distilled, mixed, decomposed, volatilised, condensed, or precipitated in an endless round, according to laws which chemists often in vain attempt to discover. All terrestrial beings pay tribute to the atmosphere; all receive from it the principles necessary for life and vegetation, and probably even inorganic existence is dependent upon it. There is perhaps no substance which is not reducible to the aeriform state by heat, and which cannot be rendered a solid by cold. Were this planet transported into the temperature which Mercury possesses, a part of our sea and of our land would evaporate, and mingle with the atmosphere; and, on the other hand, should our globe at any time wander towards the cold regions of Saturn or Uranus, a great portion of our atmosphere would be condensed and pass to the solid form. Our atmosphere therefore may be thus defined: "The assemblage of all substances capable of preserving the aeriform state at the

degree of temperature which prevails around the terrestrial globe."

The atmospheric fluids may be divided into three classes: the first comprehends *air*, the atmospheric fluid properly so called; the second consists of aqueous and other *vapours* suspended in the atmosphere; the third is composed of the various *fluids* that are *aeriform*, or supposed to be such, which shew their existence in the atmosphere, either visibly or by their effects. We shall consider the bodies comprehended under each of these classes only according to the relation which they bear to physical geography, referring such of our readers as are anxious for more detailed information, to those excellent treatises which have served as guides to us. Different species of atmospheric fluids.

Air, which forms the greatest part of the atmosphere, is not a simple element [a]. Modern chemistry, by analyzing common air, and by again compounding it, has proved that there are two substances which enter into it in very different proportions, namely, 27 parts of *oxygen gas*, which was formerly termed *pure air*, and 73 of *azotic gas*, otherwise called *impure air*. Sometimes we find only 71 parts in the hundred of azotic gas, and 2 of *carbonic acid gas* or *fixed air*. But the carbonic acid being very soluble in water, is quickly absorbed by rain, so that its continuance in the atmosphere is but momentary; besides, its gravity confines it to the lower regions. On the other hand, *inflammable air*, which is now termed *hydrogen gas*, gains the superior regions of the atmosphere by its great lightness. This gas appears to rise even to a greater height than the *acrostatic balloons*, machines which entirely owe to it their ascending force. Certain it is, that M. Gay-Lussac, at the height of 20100 feet, filled a bottle with air, which was not charged with more hydrogen than that which we breathe [b]. Air.

It is only *oxygen gas* which is fit for animal respiration. But if it existed in too great a proportion, it would be the

[a] Haüy, Traité de Physique, §§ 301—391.
[b] Libes, Dictionnaire de Physique, au mot Air.

means of exciting our vital spirits to an excessive degree, it would exhaust our strength, and in fact make us live too fast. On the other hand, *azotic gas*, as its Greek name indicates, is incapable of supporting animal life. It is then the mixture of these two gases which renders the atmosphere so favourable for animal existence.

Salubrity of the air.

Plants and insects absorb and respire azotic gas; the former especially exhale oxygen gas, only however when they are exposed to the rays of the sun. Hence the reason why the air in a fine plain lightly shaded with wood is so salubrious; whereas, in the interior of extensive forests, we generally find the air very thick and unwholesome [c]. But we can no where enjoy air better fitted to support the vital powers in just equilibrium than at sea, where the continual motion of the waters preserves the oxygen and the azote in due proportions.

Colour of air.

The air is a fluid so extremely rare and subtle, that it becomes sensible to the touch, only when in motion, for example, when the wind is blowing. In its state of purity it is equally insipid and inodorous. According to rigid Newtonians, air is *transparent*, or rather *invisible*; and the azure colour of the atmosphere arises from the greater refrangibility of the blue rays of light [d]. Other philosophers imagine, that the blue tint is inherent in air, that is, that the particles of air have the property of producing a blue colour in their combination with light [e].

Weight of the air.

The weight of the air has been made so much the subject of discussion, that we shall be very brief in our observations concerning it. Galileo has demonstrated the weight of air by the difference of weight between two vases that were filled, the one with compressed air, the other with air in its natural state. The air pumps, the ascent of water in a pipe, and the elevation of mercury in the barometer, are all so

[c] Ingenhousz, Expériences sur les Plantes.

[d] Newton, Optice Lucis. Traités de Haüy, de Libes, etc.

[e] Goethe, Essai sur la Théorie des Couleurs. Comp. Bergmann, Géographie-Physique, ii. 24. Fourcroy, Système des Connaissances Chimiques, i p. 118.

many proofs of this fact. The pressure of a column of air reaching down from the extremity of the atmosphere to the level of the sea, is equal to the weighth of a column of mercury of the same thickness, and of 28 inches in heighth. Take a tube of glass about a metre, or 3 feet 11 lines long, from 4 to 5 millimetres (about 2 lines,) in diameter, closed at one end, and open at the other; fill it with mercury, applying your finger to the orifice; invert the tube, and place the open end in a basin containing mercury; withdraw your finger, and you will observe at the same instant the mercury descend in the tube to the height of about 28 inches. In the same manner, in our common pumps, the water rises to a height of 32 feet, (10.4 metres;) now, this height is to that of 28 inches, the heighth of the mercury, in the inverse ratio of the densities of water and mercury. One and the same cause then operates here. It can be nothing but the weight of the external air which acts upon the mercury in the basin.

Of the barometer, and its use in geography.

The *barometer*, a well-known instrument, depends for the principle of its construction upon the experiment which we have just now described. This instrument, which indicates the pressure or weight of atmospheric air, serves to measure the various elevations on the surface of the earth. The rising or falling of the mercury in the barometer, is inseparably connected with the density of the air, which varies according to the weight with which it is charged. It has been demonstrated, that when the densities are in geometrical progression, the altitudes are in arithmetical progression. We can thus ascertain the one from the other. The methods of calculation invented by Deluc, La Place, and Ramond, as well as the rules for correcting the errors occasioned by temperature, can only be fully developed in those treatises specially dedicated to the higher branches of physics[f].

Physical geography ought, however, to express her gra-

[f] Laplace, Mecanique Céleste, iv. 293. Ramond, Memoires de l'Institut, Classe des Sciences, vi. 435. *qq.* Haüy, Physique, §§ 411—430.

titude to the sciences, for having brought to perfection an instrument, the multiplied use of which alone enables us, with facility and dispatch, to form extended conceptions respecting the configuration of the mountains, plains, and valleys of our globe. The pressure which the air exerts on a man, the surface of whose body is 15 square feet, is 32,505 pounds, and the variation of a single line in the height of the mercury produces a change of 138 pounds in the pressure of the air. The diminution of the weight of the air upon very high mountains, combined with other circumstances, occasions vertigos, nausea, hemorrhages, and a feeling of universal uneasiness [g]. It is probable, that at a very great height, the extreme rarefaction of the air, the absence of azotic gas, and the abundance of hydrogen gas, would cause immediate death. The proportion subsisting between the weight of air, and of distilled water at the temperature of zero on Reaumur's thermometer, and with a mean pressure of 28 inches of mercury, according to the very accurate experiments of M. Biot [h], is that of 1 to 770,30.

Effects of the diminution of weight.

Proportion between the weight of air and water.

The air exerts a pressure equal on all sides, otherwise fragile bodies would soon be broken. The moment that the equilibrium of its parts is destroyed, by whatever cause, this property produces an instant exertion to re-establish it; and this is the principle of all its movements. It is also necessary to observe that the weight of the atmospheric air, in its ordinary state, arises perhaps in a great measure from the presence of various foreign bodies which are floating in it continually. Lambert, after speaking of the difference which is found between the actual propagation of sound, and that which theory gives, has estimated, that if we consider a cubic foot of air as composed of 684 parts, 222 of these, or nearly one-third of the whole, will consist of extraneous matter [i].

[g] Saussure, Voyages, Nos. 559 et 2021.

[h] Haüy, Physique, § 394.

[i] Mémoires de Berlin, 1768.

The *elasticity* of the air is the property which it possesses of resisting the force of compression, and of recovering its original volume, or even a volume of greater dimensions, as soon as the compressing force ceases to act. We cannot exactly compute the limits of the compressibility and the dilatability of the air; we know, however, that they are of vast extent. Boyle affirms, that without the assistance of heat, he has dilated air 13,766 times [k]. Every one knows the manner in which air is compressed in an air-gun, and the force with which it can thus be made to impel a ball.

Expansive power of air.

The greater the elasticity possessed by the air, the larger space it occupies; in other words, the more it dilates itself. Newton calculated, that at the height of 87 leagues, the air would be many thousand million times more rarified than at the surface of the earth [l]. But this rarefaction must have limits. In proportion as the force with which each particle tending to escape from those which are under it, becomes less than the force of gravity which draws it towards the earth, in the same proportion the spring or elastic power of the air will be gradually weakened. The dilatibility of the air must therefore have its boundary fixed at the point where these two opposite forces shall be equal. As we do not know to what extent the progressive rarefaction of the air is carried, we are unable of course to determine the precise height of the atmosphere. There are various methods of ascertaining it, which are all correct to a certain degree, but still insufficient to conduct us to the ultimate boundary. If we agree with Deluc [m], and regard the air as æther condensed by gravitation, it will follow, that if the earth were the only great body in the universe, its atmosphere would know no bounds. But, as there are other globes, air at a certain distance must commence to gravitate towards them, and, gradually ceasing to dilate, will condense itself anew. This however conveys to us no positive informa-

Height of the atmosphere.

[k] Wallis, Hydrostat. Prop. 13.

[l] Newton, Optice, Quæst. 28.

[m] Modifications de l'Atmosphere, vol. ii. p. 248.

tion. Astronomers avail themselves of refractions, which are sensible to 18 degrees below the horizon, but they vary with the temperature; however, by taking a medium, we may conclude the height of the atmosphere to be 228,000 feet, or between 15 and 20 leagues[n]. The barometer would furnish a sure and easy mode of resolving the question, if air was not compressible; but the different extent of beds, or portions of air, of the same weight, and the pressure of heterogeneous bodies, render the calculation long and uncertain. Deluc has found that the height of the atmosphere, taken at that point where the mercury shall rise only one line, will be 150,600 feet, or about 11 leagues, and that where the mercury is elevated in the tube only one-tenth of a line, the height will be 213,030 feet, or about 15 leagues and a half.

Variations of the height of the atmosphere.

The terrestrial atmosphere either dilates or compresses itself according to the prevalence of heat or of cold. Under the equator, the rarefaction produced by the rays of the sun unites with the centrifugal force in causing the atmosphere to swell in such a manner as to form around the earth a spheroid extremely flattened. Laplace imagines that the difference between the two axes cannot, at its maximum, be less than that of 2 from 3. It is very natural to suppose that there is a kind of flux and reflux in the atmosphere, corresponding to the tides of the ocean. But D'Alembert and Boscovich have shewn that the attractive powers of the sun and moon act but feebly upon so subtle a fluid as the atmosphere[o].

Evaporation. Its two methods.

The immense quantity of particles which terrestrial bodies emit by evaporation, rise into the air under the form of vapours. Under the equator this transpiration of the globe is very strong, and even the polar cold does not entirely prevent it. According to some philosophers, there exists a great difference between *tranquil evaporation*, by

[n] Lalande, Astronomie, vol. ii. p. 559.

[o] Mann, Mémoire sur le Flux et Reflux de l'Atmosphère, dans les Mémoires de l'Académie de Bruxelles, tom. iv.

which only the particles of water, transformed into an elastic fluid rise in the air, and *tumultuous evaporation*, in which the elastic vapours, disengaging themselves with great rapidity, carry along with them a great number of aqueous particles in their natural state[p].

Tranquil evaporation, which takes place in temperate and cold regions, does not so much change the natural state of the atmosphere as the tumultuous evaporation, which is in continual operation in the torrid zone. The aqueous particles, which are numerously diffused through the atmosphere in hot countries, deprive it of a portion of its caloric, and, consequently, of its elasticity, which renders it less sensible to every kind of commotion, and explains the great steadiness of the barometer in that zone. It is certain that neither the periodical rains, nor even the hurricanes, can disturb the uniform tranquillity which the barometer exhibits in the neighbourhood of the equator; whereas, the nearer we approach the pole, so much the more considerable do its oscillations appear. This variation of weight in the atmosphere in the temperate zones can be attributed only to the variations of elasticity produced by evaporation. The different nature of terrestrial substances also, serves to modify evaporation. The azotic and carbonic gases abundantly disengaged from many rocks and earths, cannot be unconcerned in that chemical operation by which the atmospheric fluid is unceasingly renewed. A number of earthy particles, reduced to extreme tenuity, rise in the air, as is evident from the saline and sulphureous showers which sometimes fall. Even the quantity of the evaporation depends upon the kind of substances composing the surface of the globe. Earth, mixed with water, furnishes more vapours than pure water[q]; owing undoubtedly to a sort of fermentation which disengages a greater portion of caloric[r]. From a similar cause, water evaporates more powerfully at

Nature of evaporations.

[p] Hube, sur l'Evaporation, p. 49—52, 103—402.

[q] Bazin, Mémoire de l'Académie de Paris, 1741.

[r] Is it not rather owing to the greater quantity of surface which the water thus moistening the earth, exposes to the action of the atmosphere? T.

the moment of its congelation. The air is impregnated with an immense quantity of vapours from numerous plants; the evaporation from the *helianthus annuus*, is 17 times greater than that from an equal extent of the surface of the human body. What then must be the influence of those thick forests which in many countries still cover such vast spaces!

The majority of natural philosophers having not yet with sufficient minuteness examined the various ways in which evaporation is modified, are content with affirming, that part of the water which rises in vapour is intimately mingled with the atmospheric air which dissolves it; this water is invisible; but when the air is saturated, the watery particles which continue to rise are no longer dissolved, but remain suspended in vesicular vapours, the union of which forms the *clouds* and *mists*, and gives rise in general to all *aqueous meteors*. It happens also, that a part of the water dissolved by the air in disengaging itself anew, from whatever cause, assumes the form of vesicular vapours.

Aqueous meteors.

Aqueous meteors present themselves to our view under two forms: suspended in the air as mists and clouds, or falling to the ground like dew, rain, and snow. Cold, by condensing the vapours which are already elevated in the air; heat, by rarefying the air, and by disposing and exciting the vapours to disengage themselves and ascend from the earth, and, in short any change whatever in the physical constitution of the atmosphere[s], produces that visible union of vapours termed *mists*, when they are extended over the surface of the earth, and *clouds* when they float in the air. In ascending to the summit of mountains the traveller frequently passes through a zone of clouds, and beholds the extensive vapours of which it is composed stretched under his feet like a vast plain covered with snow[t]; but even on Chimborazo, the loftiest mountain of the Andes, there are always to be seen, at an immense height, certain whitish

[s] Bergmann, Géographie-Physique, § 113, 114.

[t] Reichardt, Voyage aérien, Gazette de Berlin, Juin, 1811.

clouds, resembling flakes of wool. These clouds, which are perhaps a hundred leagues from the globe, probably owe their elevation to that negative electricity with which they are charged, which repels them from the earth, while positive electricity occasions the mists to descend [u].

Deluc observed a very elevated cloud descend with rapidity towards the earth, scatter around a violent shower of rain, and then with equal velocity remount to its original height. This was evidently the effect of electricity [v].

Mists are of two kinds, *dry* and *wet*; the latter are sel- Mists.
dom to be met with in the torrid zone, but they continually brood over the polar regions. It is easy to account for this difference; the habitual compression of the atmosphere and its density being much greater towards the pole, vapours can rise and detach themselves from the earth. The *dry fogs*, according to some philosophers, arise from subterraneous vapours; they exhibit an intimate connection with volcanic eruptions. Such was the case with the celebrated mist which in 1783 enveloped all Europe, at the moment when the volcanic fire made Iceland tremble, and immediately after the disaster of Calabria [x].

In 1755, before the dreadful calamity which befel Lisbon, a similar fog overspread the Tyrol and Switzerland; it appeared composed of earthy particles reduced to an extreme degree of fineness [y]. Among the aqueous meteors Dews.
which fall to the earth, none has given rise to more conjectures than *dew*, for it appears to have a two-fold origin; it may in part be produced from the transpiration of plants; but the greatest quantity is formed by the precipitation of vapours, which, during a warm day, have been elevated to a considerable height. The influence of electricity in this phenomenon, is quite undoubted, although as yet indistinctly explained; for it is only after a day in which the

[u] Hube, sur l'Evaporation, chap. i. p. 291, *sqq.*

[v] Deluc, Modifications de l'Atmosphère, ii. 721.

[x] Beroldingen, Réflexions sur le grand brouillard. Brunswick, 1783, (en All.) Majra in de Physique de Gotha, ii. 9, iv. 114, v. 119.

[y] Lambert, Act. Helv. tom. iii. Bergmann, Géographie-Physique, § 131

air has been highly electrical[z], that the dew is found in abundance; and it is no where formed in larger quantities than on the surface of bodies which are non-conductors of electricity, as glass and porcelain. Metals, on the contrary, appear to absorb it. There is hardly any dew in the Polar regions, in dry climates, or on the coasts of seas in temperate zones. It is much more abundant in hot countries, where it is often a substitute for rain; but, in several places, it is equally hurtful to the growth of plants, and to the health of man, particularly in marshy countries, where the vapours which rise during the day are of a very unwholesome nature.

White or hoar frost.

Hoar frost is a kind of dew which has frozen the moment it falls. When attached to trees stripped of their foliage, it presents the appearance of crystallized vegetation.

Rain.

Rain falls from the clouds, when the vesicular vapours, of which it is partly composed, unite into drops. These drops, in our climate, are only a few lines in diameter, but in the torrid zone they amount to an inch. So that the difference which we remark between the ordinary rain and that which falls during a storm, appears to be only accidental, and the origin of both may be attributed to a diminution of electricity in the clouds. Mountains constitute so many points which draw off the electric fluid, and hence it rains almost continually in certain hilly countries, as on the eastern side of Norway and Scotland. In those regions where thunder is unknown, as in the environs of Lima, and on the side of Peru, rain is a phenomenon equally unknown[a].

Snow.

When aqueous vapours are congealed, either while falling, or when in the air previous to their falling, they form *snow*. The ordinary crystallization of sal ammoniac in little feathery crystals, presents phenomena similar to those

[z] Du Fay, Mémoire sur la Rosée. Mémoires de l'Acad. des Sciences, 1736, p. 352.

[a] Hube, sur l'Evaporation, chap. 51, 56, p. 296, 328.

which take place in the crystallization of snow[b]. "If," says M. Monge, "we fill a deep glass to which heat has been applied, with a saturated solution of sal ammoniac in a warm state, and then let it gradually cool in a calm air, the surface of the liquid will be the first to arrive at the point of supersaturation, as well from the direct cold which it experiences, as from the concentration which the evaporation promotes in that part; it is on the surface, then, that the first crystals are formed. These crystals, which are extremely minute, sink as soon as they are formed; and they descend with slowness, because their specific gravity is not much greater than that of the liquid which contains them, at the same time their volume increases by the addition of similar crystals, which are formed during their descent, so that they reach the bottom of the vase in large white flakes. The rapid progress of the crystallization is entirely owing to the affinity of the particles. The first crystal which begins to descend, forms, as it were, a rallying point, or nucleus, to all the particles which have a tendency to unite." By a reference to these phenomena, we may explain the formation of snow; the first crystals of which, produced at a great height in the atmosphere, determine, as they descend, by the excess of their specific gravity, the crystallization of aqueous particles, which, without their presence, the surrounding air would have retained in a state of solution. The result is the formation of stars of six rays, when the weather is sufficiently calm, and the temperature not too high to deform the crystals by melting off their angles; but when the atmosphere is agitated, and the snow falls from a great height, the crystals clash together, unite in groups, and form irregular flakes.

Hail, according to all appearances, is a species of snow, or of snowy rain, which has undergone a variety of congelations and superficial meltings in its passage through different zones, some temperate, and others frozen. But what cause can produce these great variations of tempera- Hail

[b] Monge Annales de Chimie, v. 1. p. 74.

ture? We answer, electricity, which, in combining oxygen and hydrogen, deprives them of part of their caloric[c]. Hail, accordingly, even that which falls in spring, is accompanied by marks of electricity[d]. It is by an electrical apparatus that we can produce artificial hail[e]. We may add, that volcanic eruptions are often followed by the fall of hailstones of enormous size[f]. The violence with which hail is discharged upon the earth, under an oblique angle, and independently of the wind, would be explained by supposing, with the celebrated Volta, two electrical clouds drawn towards each other in a vertical direction, and by their shock producing hail, which, by the law of the composition of forces, would then be projected in the diagonal of its gravity, and of the result of the two directions of the clouds.

Effects of aqueous meteors.

Such are the principal circumstances which natural philosophy has supposed to concur in the formation of aqueous meteors. Their beneficial influence upon the earth is a point more easy to determine. We observe all nature languish, when the atmosphere retains for too long a time the fluid arising from the earth. Plants fade and droop; animals feel their strength failing them. Man himself, breathing nothing but dust, can with difficulty procure shelter from the sultry heat by which his frame is parched and overpowered; but scarcely have the waters of heaven descended from the clouds, when all living beings begin to revive; the fields resume their green attire, the flowers their lively tints, animals the sportive freedom of their motions, and the elements of the air their healthful equilibrium. Snow itself, whose very name alarms the

[c] Journal de Physique, ou Observations, &c. de Rozier, 1778, Sept.—Cotte, Journal General de France, 1788, No. 95. Magasin de Gotha, vi. &c. Libes, Dictionnaire de Physique.

[d] Senebier, Journal de Physique, 1787, Mai.

[e] Quinquet et Seiferheld, voyez Magasin de Gotha, vi. 189; vii. 45—47, &c.

[f] Stephenson's Picture of Iceland, p. 307, (in German.)

natives of the tropics, is productive of real advantages in the economy of nature; it secures the roots of plants against the effects of intense cold; it serves gently to moisten those lands from which, owing to their local situation, the rain is too soon carried off; and it paves for the inhabitant of the north commodious and agreeable roads, along which he gaily skims in his light and nimble sledge; whilst the occupants of the south, living under a cloudy sky, are strangers to the enjoyments both of winter and of summer. Hail alone, of all the aqueous meteors, never appears but as a harbinger of distress. Birds and quadrupeds instinctively conceal themselves, as soon as they have any presentiment of its coming [g]. Man can neither foresee its approach, nor arrest its ravages; he has been able to ward off the thunderbolts of the sky, but he sees the hail destroy his corn, break his fruit trees, and shatter the very house where he dwells, without being able to prevent it.

Excess of humidity might soon become hurtful to the earth, but it is difficult for such excess to take place; the quantity of atmospherical water diffused by aqueous meteors varies according to the climate. At Paris, it has been found that there annually fall 24 inches of rain-water and of dew; at Iolmezzo, in Friuli, the quantity of rain alone amounts to 82 inches; at Carfagnano, in the Apennines, to 92; there fall at Grenada, 105; and at Leogane, in the island of St. Domingo, 150 inches. It is probable that in every place the quantity of water evaporated, determines that which descends from the atmosphere [h]. Quantity of atmospheric water.

The salutary effects of aqueous meteors are modified by the chemical qualities of the waters of the atmosphere. The salt rain and dew in the environs of the Caspian Sea, owing to the vapours which arise from a soil impregnated Nature of atmospheric water.

[g] Cours complet d'Agriculture pratique, par Rozier, Sonnini, &c. art. *Météorologie.*

[h] Delamétherie, Théorie de la Terre, sect. 1254. Cotte, Météorologie. Hales, Statiques des Végétaux. Mémoires de Sedilleau (Academie de Paris) de Wargentin (Academie de Stockholm,) &c. &c.

with different kinds of salt[i], probably contribute to those saline efflorescences, which, according to M. Olivier, are gradually overspreading the once fertile soil of Persia. They are so strong, that in one cold summer night, you may see them on the camels, under the appearance of hoar frost containing sal-ammoniac. In the west of Jutland, you may perceive fogs of a salt quality arising from the bosom of the sea, which consume the foliage of trees, and put a stop to their growth, without being pernicious to that of grass. In France, the autumnal fogs, charged probably with electricity, hasten sometimes the maturity of the grape.

Showers of blood, of sulphur, and of fire.

Amongst the aqueous meteors, there are some which were once considered as miraculous, but which more exact observation has entirely divested of their supernatural character. Such are *showers of blood*, which take place when the rain water draws with it a great number of certain red insects, which float in the atmosphere, or swarm on the earth. *Showers of sulphur* may actually have occurred, even independently of volcanic eruptions, as the air contains carbon and sulphuric gas, which, combined by caloric, form sulphur. In the month of May, 1646, there rained at Copenhagen a kind of substance, which, on being examined by the philosophers of that day, appeared to be a mineral sulphur[k]; but the same phenomenon recurring in 1804, and in the same month of May, the philosophers of the present age, after analysing the precipitated matter, perceived only a vegetable substance nearly resembling the *semen lycopodii*[l]. The phosphorescence of this substance, at the moment of the rain, which happened during the night, presented an alarming spectacle. Other examples concur in shewing that sulphurous showers are in general nothing but the fall of a vegetable powder, taken up by a water-spout; a phenomenon which we shall hereafter de

[i] Gmelin, Description de la Russie, iii. 11, 12.

[k] Wormius, Museum, lib. i. cap. 9, sect. 1.

[l] Mémoires de Viborg et de Rafn.

scribe. At Bourdeaux, in 1761, the wind raised, and bore through the air a cloud composed of a sort of yellowish dust, covering the stamina of the flowers of the pine-trees in the neighbouring *landes* [m]. Hurricanes too have sometimes lifted up sheaves of corn, as well as animals of small size, such as locusts and toads, which, falling at a considerable distance, have frightened the peasants. The most frightful phenomenon of this description, a shower of fire, has been twice observed by a celebrated naturalist, who declares he saw nothing more than rain very strongly charged with electricity, and which sparkled on touching the ground [n].

We come now to consider luminous meteors; and first as to those which, according to the principles of common physics, depend on refraction and reflection. Optical phenomena.

The solar rays, say the Newtonians, in passing from a rare into a dense medium, undergo an inflection, a deviation from the direct line of their course, which is termed *Refraction*:—the seven visible rays have different degrees of refrangibility: the red rays have the least; then come in succession the orange, the yellow, the green, the light blue, the indigo, and the violet. All bodies, which are visible without being luminous or transparent, have the property of *reflecting* light, that is, of repelling it, and throwing it back. Even the clouds and the air possess this property. The rays, which have most refrangibility, are also the most reflexible. These two causes present us with the most delightful and the most majestic spectacles in nature. If the sky shines with a beautiful azure hue, it is solely the effect of the rays of blue, indigo, and violet, which are first reflected from the earth, and afterwards returned to us by the atmosphere. The refraction of light enables it to diffuse itself gradually over our hemisphere, obscured by the shades of night, long before the sun ap- Refraction and reflection.

[m] Sigaud Lafond, Dict. des Merveilles de la Nature, tome iii. p. 196.

[n] Bergmann, Géog. Physique, ii. 15. sect. 115.

pears, even when that luminary is 18 degrees below our horizon.

Twilight and Dawn.

The *twilight* and the *dawn* confer a substantial benefit on the labourer, the navigator, and the wretched inhabitants of the frozen zone. By their means the two poles enjoy the solar light for nearly the space of nine months. The sun himself appears by refraction above the horizon before he actually arrives there.

Rising and setting of the sun.

The brilliant tints which accompany the *rising and setting of the sun*, originate from this, that the air towards night and in the morning is considerably condensed, and loaded with a variety of vapours. The very refrangible rays seldom or never reach us. The red and yellow have alone inflexibility enough to penetrate through the atmosphere, and to render the vapours and clouds so many moveable mirrors. This then is the reason why the sun appears so often to be red, morning and evening. The delightful spectacle of the dawn and of twilight is almost entirely denied to those who live in the regions of the equator, where the sun rises in a direction nearly vertical. It is towards the poles that these reflected splendours of that great luminary are longest visible, often changing the whole of the night into a magic day, of which the inhabitant of the south of Europe can form no adequate conception.

Parhelions.

Parhelions, or false suns, are phenomena less common. We see by the side of the sun, often above and below, several images of that luminary, more or less bright. These *false suns* are sometimes surrounded by a circle of pale light; sometimes adorned by the colours of the rainbow; most commonly they are not exactly circular, and some have been observed with luminous trains. This meteor has never been seen at the same time in a number of distant places; it exhibits a different appearance even to spectators who are near each other; it is therefore an optical illusion. As it snows and hails generally at the very time when a false sun disappears, it is supposed that it is in a mass of little spires of ice suspended in the air that the image of the sun is reflected; the rays pass probably through an opening be-

tween thick clouds, as when one lets fall the solar image in a camera obscura [o].

There are also false *moons*. These illusions can take place only when the sun, being distant from the zenith, darts its rays obliquely upon the atmosphere; accordingly, almost all the parhelions occur either in the morning or the evening. False suns are often observed in countries where a damp cold prevails. These are frequent phenomena in Greenland; and we are assured, that in the environs of Hudson's Bay, the sun, when rising, generally appears to have a tail.

The *rainbow* has a near affinity to parhelions, and gene- Rainbow.
rally accompanies them. Every one knows that this magnificent arch, so wonderfully coloured, is the effect of the seven solar rays refracted in drops of water suspended in the air, and reflected upon a dark cloud, as upon a canvass. It is to treatises on optics that we must refer our readers for an explanation of this phenomenon [p].

What is termed the *apotheosis* of travellers, is a pheno- Various kinds of reflections.
menon much akin to that of the rainbow. The academicians Bouguer, Godin, and La Condamine, when standing upon the very elevated mountain of Pambamarca, in Quito, saw their own image reflected in a very light fog, and surrounded by several concentric circles, ornamented with the colours of the rainbow. The *Spectre of Brocken* is an optical deception of the same kind.

The "*Mirage*," or appearance of objects which are not The mirage.
actually in the horizon, or which exist there in a different situation, is one of the most remarkable of optical illusions. At sea, rocks and sands concealed under the water, appear as if they were raised above the surface. The Swedish sailors long searched for a pretended magic island, which from time to time could be descried between the isles of

[o] Huyghens, Dissert. de Coronis et Parheliis, in Op. Relict. ii. Bergmann, Géographie-Physique, § 122.

[p] Haüy, Traité de Physique, §§ 955-975. Comp. Observations sur l'Arc-en-Ciel, suivo de l'application d'une nouvelle Théorie, &c. par M. l'Abbé P. Paris, 1768.

Aland and the coasts of Upland. It was a rock elevated by the mirage [q]. At one time, the English saw with terror the coasts of Calais and Boulogne apparently approaching the shores of their island.

Vessels sometimes present themselves to the view, as if they were upset, or as if sailing in the clouds [r]. The most celebrated example of this phenomenon is that which is frequently seen in the straits of Messina, and which the people attribute to the fairy Morgana, *Fata Morgana*. The spectator, standing on the Italian coast, perceives, upon an inclined plane, formed by the waves driven towards the middle of the strait, images of palaces, embattled ramparts, houses and ships, at one time turned upside down, at another confusedly set up again, and presenting the spectacle of towns and landscapes in the air [s]. Of all the effects arising from this cause, that which has been most thoroughly examined, is the optical illusion which the French experienced in the deserts in the vicinity of Egypt; the sandy plain, covered in the distance by a thick vapour, presented the deceptive image of a vast lake, towards which they eagerly hastened, but which appeared to fly before them [t]. All these fantastic optical appearances, worthy of exercising the acuteness of philosophers, who unquestionably will trace through each of them only the varied effects of a single cause, can be but briefly specified in a treatise of physical geography.

Zodiacal light.

The *zodiacal light* deserves our particular attention. It is a grand phenomenon, which must be referred either to the nature of the terrestrial atmosphere, or to the position of the globe with regard to the sun. This light, which exists constantly under the equator [u], presents itself after sunset,

[q] Mémoires de l'Académie de Stockholm.

[r] Minasi, Gilbert, &c. Voyez le Mémoire sur les Fata Morgana, qui paraîtra dans les Annales des Voyages.

[s] Philosophical Transactions, 1799.

[t] Monge, sur le Mirage, dans les Mém. d'Egypte, i. 64.

[u] Horner, Astronomie de l'Expédition de Krusenstern, dans Zach, Correspondance, x. 211, 219, 340, (avec une figure.)

under the appearance of a serene whitish clearness, of a lenticular form, having its base turned towards the sun, and its axis in the zodiac.

Mairan has supposed, that this light was the atmosphere of the sun [x]; but this explanation, so generally admitted, is totally rejected by M. de La Place. This illustrious geometer observes, as we think very justly, that the atmosphere of the sun cannot have a lenticular form, nor be extended beyond the orbit of Mercury, whilst the zodiacal light appears to extend itself even beyond the terrestrial orbit [y]. If we were permitted, in a work of this description, to develop new opinions in physics, we should endeavour to render it probable, that the zodiacal light is nothing else than the luminous fluid belonging to the terrestrial globe, attracted by the sun in the direction of his apparent daily path, and which, being accumulated upon the line of that direction, becomes visible at the moment of the decline of the sun. This efflux, forming an elliptic belt, the great diameter of which is always directed towards the sun, must present itself under a lenticular figure, the largest part of which is turned towards that luminary. It is true, that this explanation supposes that the luminous fluid, diffused throughout the universe, accumulates around the celestial globes in the ratio of their mass and density, which as yet is only an uncertain hypothesis.

Igneous meteors.

Amongst the *igneous meteors*, of which we are now about to treat, *thunder* occupies the first rank. It is universally known to be the effect of electricity, the theory of which must be studied in philosophical treatises. We have seen, that all the powerful agency of the electric fluid is sensibly present in the air, in rain, snow, hail, and in the clouds which float in the midst of the atmosphere. These bodies receive their electric properties from the hand of nature, in a manner not exactly known, though the experiments of Lavoisier and La Place have unquestionably prov-

[x] Mairan, Traité de l'Aurore Boréale, p. 12.
[y] Laplace, Système du Monde, lib. v. c. 10

ed, that terrestrial bodies, in evaporating, carry up from the earth a part of the electric fluid which belongs to it. It is to the celebrated Franklin we owe the direct proof of the electricity of the atmosphere. He was the first who was bold enough to make an experiment on the clouds, and to draw down the lightning from the sky.

The electricity of the clouds in storms is almost always that which philosophers term *vitreous* or *positive*; it augments in proportion as we ascend in the atmosphere, and consequently ought to be very strong in that part of the air which gives birth to storms. The whole terrestrial globe may be looked upon as a vast reservoir of both kinds of electricity, but more frequently of the resinous or negative. As long as these two bodies remain in their natural state, the two electricities consequently are in equilibrium, and at rest; but if one of these two bodies, whether it be the earth or the atmosphere, acquire an excess of the electric fluid, there is no longer an equality between the repulsive and the attractive powers. The excess of the fluid is discharged in the form of a flash. This constitutes thunder, which is either *descending* or *ascending*. We sometimes observe these two kinds of thunder almost at the same moment, the earth and the atmosphere appearing to make a mutual exchange of their surplus electricity. The flash, which is attracted and conducted by metals and moist bodies, in preference to other substances, commits ravages which, from our inability to observe them with coolness, still remain in circumstances of obscurity; here, the thunder kindles rapid and devouring flames; there, it bends and shivers the objects which it meets with. Sometimes it instantaneously deprives animals of life, and sometimes it passes over the clothes without injuring the person.

Variations of the electric fluid.

A kind of periodical flux and reflux has been observed in the electrical fluid of the atmosphere. In summer, when the earth is dry, and the day is warm, droughty, and serene, the atmospheric electricity increases from sunrise till mid-day, when it arrives at its *maximum*, then it remains stationary for a couple of hours, and afterwards di-

minishes until the fall of the dew. Towards midnight, it revives, to be again almost entirely extinguished. In winter, the *maximum* of electricity is at eight o'clock in the evening; it is weaker during the day. In all these variations, atmospherical electricity seems very exactly to follow up the development of hydrogen gas, which is more or less considerable at different periods of the day[z]. Electrical phenomena are more prevalent in some quarters of the globe than in others. Towards the poles, the disengagement of hydrogen gas is extremely scanty, and there is also no continual friction between the earth and the atmosphere. Thunder, accordingly, is rarely observed in those regions; it is only a weak decrepitation. As we advance towards the equator, hydrogen gas becomes more abundant, and at the same time the storms are more violent. It is under the line, that we meet with that vast extent of sea where thunder storms almost constantly prevail. There are, however, countries under the line, in which it rarely thunders. If thunder seems to be particularly attracted towards marshy places, may not the cause be found in the presence of the inflammable gas of marshes, which is only an impure species of hydrogen gas? It is supposed that there are, in the electric fluid of the globe, two currents, the one from the poles towards the equator, the other in an opposite direction. This is a very probable hypothesis.

Effects of storms.

Storms, notwithstanding the calamities which they frequently occasion, and which the thunder-rod cannot infallibly prevent, deserve to be considered as one of the greatest benefits that our Creator has bestowed. They diffuse freshness through the atmosphere when it is in a confined and sultry state; the plants resume their lively green, the flowers raise their drooping heads when their thirst has been quenched by the rain; the crops and fruit, penetrated by new warmth, ripen more rapidly, and man silently adores the Great Being whose power has been displayed

[z] Saussure, Voyages, sect. 800, 803, 831. Lamanon, Mem. de l'Acad. Royale, 1782, p. 240, 241. Beccaria, Electricite terrestre, sect. 1087.

We now proceed to consider other igneous phenomena, none of which possess the dreadful energies of thunder.

Aurora borealis.

The *aurora borealis*, so often celebrated by Ossian, presents a spectacle equally magnificent and astonishing. In these bloodstained and fiery meteors, what poet is there who could not discover the shades of warriors, who, once conquerors of the earth, and now rulers of the air, stoop from the clouds to behold the combats of their posterity? Are not those pale and soft lights the daughters of heroes who, cut down in the early bloom of their beauty, now float upon the wings of the wind? We hear their sighs, and the rustling of their resplendent robes; and we see, rising towards the zenith, and assembling on every side the luminous columns of the wandering palace of departed spirits. But we must leave to the painter and the poet the delineation of such enchanted scenes, and confine ourselves to a more rigorous and sober description[a]. The aurora borealis, in our European countries, uniformly appears in the north, and inclining generally a little to the west. In Greenland, we sometimes perceive this phenomenon towards the south. In the other hemisphere it is observed, but with a feeble lustre, in the direction of the south pole. The ancients appear to have described it under the name of *lamps*, or *burning torches*, and other designations. In our age, it is a rare occurrence in the temperate zone, and becomes common only towards the 60th degree of latitude. It commences generally three or four hours after sunset, and is preceded by a sombre cloud, nearly resembling the segment of a circle, of which the horizon forms the cord. This segment, seen at Upsal, for example, is of a deep black, whilst in Lapland it appears greyish, or even becomes almost invisible. Its circumference very soon borders upon a whitish light, which sometimes appears gently to expire. Most frequently the cloudy segment opens in chinks, whence issue streams and rays of light, of a yellow, a rose-

[a] Mairan, Traite des Aurores Boréales, p. 115. Bergmann, Geog. Phys. n. 96—101.

a purple, or a sea-green colour. A general movement agitates all the cloudy and enlightened space; rays becoming more and more bright, shoot across each other like lightning flashing in the midst of effulgent splendour; by degrees, there is formed in the zenith a luminous crown, which seems to be the central point of all the motions of the luminous matter. After having occupied, for the space of an hour or two, almost the whole expanse of the heavens, the phenomenon contracts itself at first on the southern side, afterwards on the west and the east, and finally disappears towards the north. The rising sun invariably extinguishes these rival luminaries. The further we remove from the pole, the less distinctly do we perceive these different appearances of the aurora borealis. It generally appears in France, only like a light not much elevated above the horizon.

Philosophers have given different explanations of these phenomena. That which Professor Libes lately proposed, appears to unite simplicity to probability [b].

This philosopher lays down the six following principles: 1st, If the electric spark be transmitted through a mixture of azotic and oxygen gas, the result is the production of nitric and nitrous acids, or of nitrous gas, according to the proportion subsisting between the oxygen and azote which compose the mixture. 2d, Nitric acid acquires additional colour and volatility from being exposed to the sun. Scheele first observed this phenomenon, and M. Libes has made frequent observations on the subject. Having placed a glass receiver over a saucer containing nitric acid, and having exposed the whole to the sun, he observed that the acid became coloured, and that the receiver was filled with reddish-looking vapours, which remained in it a long time, diffusing a lustre similar to that of the aurora borealis. 3d, In phials containing nitrous acid, we always perceive above the acid a very red and very volatile vapour, which never condenses,

[b] Traité de Physique, par Libes, tome iii. p. 309.

4th, Nitrous gas, when in contact with atmospherical air, emits deep red vapours, which fly away into the atmosphere. 5th, The hydrogen gas which is disengaged from the surface of the globe, occupies, in the higher regions of the atmosphere, a place marked out by its specific gravity. 6th, The solar heat has but little influence in the polar regions. In reflecting upon these principles, it is easy to perceive, that the production of hydrogen gas being extremely scanty, if at all occurring, in the polar regions, the electric fluid in flowing back from the equator towards the pole, must pass through a space occupied only by a mixture of azotic and oxygen gas; that the electric spark fixes and combines these two gases; that this combination ought to cause the production of nitrous acid, or of nitrous gas, according to the proportion which prevails between the two component gases; and that the gas and the nitric acids thus formed, should exhale red and volatile vapours, which give rise to the phenomena of the aurora borealis. If these phenomena do not occur in the temperate zones, the reason is, that in their strongly heated atmosphere, there is always to be found a mixture of oxygen and hydrogen gas, which attracts the electric spark, thus occasioning thunder and lightning. These two phenomena are not known in the polar regions, from their deficiency in hydrogen gas.

The observations of the elder Gmelin, in his travels in Siberia, tend to confirm the opinion of M. Libes. As we advance into eastern Siberia, the aurora borealis becomes more frequent and more dazzling; and it appears that the frozen regions, between Jenissa and Cape Behring, are the native country of these phenomena. Now, that is exactly the quarter of the old continent where the cold is most intense, and consequently where least hydrogen is disengaged.

This explanation, however, does not account for several circumstances of the phenomenon; amongst others, for the blackish segment which forms the base. We must wait until enlightened observers have applied the principles on which it is founded to a certain number of these pheno-

mena. We would ask these observers, whether the aurora borealis might not be in some measure the effect of one of those optical illusions of which we have been speaking, viz. the mirage? and whether the circular segment be not the image of the terrestrial globe itself, repeated in the nocturnal atmosphere? And then the luminous rays which appear to issue from this cloudy segment, would in fact issue from the earth itself. This is a solution which we submit to the examination of philosophers.

Other igneous phenomena recal us towards the surface of the earth. We know that animal substances, in a state of putrefaction, always emit phosphorus, which, taking fire from the contact of the atmosphere, produces light and wandering flames. Such is probably the origin of those *ignes fatui*, which flutter at night over church-yards and fields of battle, and which have given rise to pretended apparitions of spirits in churches where it is the pernicious custom to accumulate the remains of the dead. Hydrogen gas is often combined with phosphorus; this mixture is not fit for respiration; it quickly suffocates. This is also a circumstance which seems to enter into many histories of spirits and apparitions, namely, the inflammable air disengaged from marshes, which is hydrogen gas mixed with azotic. The air which inflames on the surface of certain springs, known by the name of *burning fountains*, arises from the presence of hydro-phosphoric gas, or as it is otherwise termed, phosphuretted hydrogen. One of these springs is met with in the parish of Saint Bartholomew, in the department of the Isere. The disengagement of inflammable gas during the summer, is so considerable, that we continually see a flame seven feet high; and travellers, when they first behold it, imagine that the whole village is on fire [c].

Ignis Fatuus.

Burning Fountains.

Ignes fatui, arising from the development of phosphureted hydrogen, are necessarily soon extinguished;

[c] Bouvier, Journal de la Médicine Eclairées par les Sciences Physique, tom. iii. No. 8.

a succession of these fires will therefore appear to the spectator to be one single flame, which moves with rapidity from place to place, when we attempt to approach it. The air, driven on before us, forces the lambent flame to recede [d]. There are other similar fires, which appear to be immoveable when viewed from a particular spot. There was one near Rettwick, in Sweden, which was supposed to issue from the mouth of a dragon that kept watch over some hidden treasures. A simple miner ventured to sink a shaft, which discovered a cavern filled with sulphurous pyrites and petroleum, the combustion of which had occasioned the phenomenon [e].

Falling Stars.

Falling, or *shooting stars*, are appearances every where observed. They are probably the effect of hydrogen gas more or less sulphureted, for phosphorus is too rapidly inflamed, by the contact of the air, to be capable of reaching so great an elevation. What seems to prove the hydrosulphureted origin of these meteors, is the nature of the circumstances by which they are accompanied. These fires, we are assured, often fall to the ground; and nothing is found at the place of their fall but a fetid, glutinous matter, of a whitish colour, bordering upon yellow. Now, we know that sulphureted hydrogen gas holds sulphur to it in solution; that the hydrogen and the sulphur does not burn at the same moment; that, consequently, the sulphurous part may be precipitated to the earth, whilst the hydrogen, mixed with the oxygen of the air, is kindled by a slight electric spark.

Fire of St. Elmo.

The *Fire* of *Saint Elmo* is generally considered as an accumulation of electric matter around a point, which moves in the air. This fire, then, may be expected to appear frequently at the top of the masts of a vessel sailing along with rapidity. The ancients observed this phenomenon. These fires, when seen in pairs, were called *Castor* and *Pol-*

[d] Derham, Philosoph. Transact. No. 411.

[e] Memoires de l'Académie de Stockholm, 1740. Bergmann, Geog. Phys. ii. 80.

lux; when the flame was single, it bore the name of *Helen*. The spears of an army often appeared ornamented with these electrical plumes [f]. A Swedish naturalist, travelling on horseback in snowy weather, saw his fingers, his switch, and the ears of his horse covered with a fire of this description [g].

Globes of fire present a spectacle much more imposing than all the preceding phenomena; they are seen of an immense size; their light is sometimes red, but oftener of a vivid and dazzling whiteness, like the flame of zinc mixed with nitre: they move with the rapidity of lightning, and appear to belong to the higher regions of the atmosphere, as they have been observed at the same time in places very distant from one another. This, however, may be only a continuation of their rapid flight, sometimes shooting along at the rate of six leagues in a second. We see them often in the space of a few seconds appear to traverse the horizon, blaze like fire-works, then break in pieces, or discharge torrents of flames, with a detonation that shakes the air and the earth at the moment of their explosion. There are some which are precipitated like a thunderbolt, break through the roofs of houses, destroy animals, and dismast or shatter vessels. At other times, they move over the earth like a whirlwind of flame, set fire to trees, devour, or at least overthrow, every thing which obstructs their course. They are occasionally accompanied with thunder. Electricity and hydrogen, perhaps also nitrous gas, seem to act here an important part; but the appearance of these phenomena is so momentary, that we cannot examine them with the requisite care. It is only, then, on hypothesis, that we consider the stones thrown down from the air as the kernels of those little comets of the terrestrial atmo- Globes of Fire.

[f] Homer, Odyssey, xx. 133. Cicero, de Divinatione, i. 18. Virg. Georg. i. 478. Pliny, Hist. Nat. ii. cap. 37. Seneca, Quæst. Nat. i. 1. Cæsar, Bell. Africa, 6 liv. xxii. 1.

[g] Forskael, dans Bergmann, Géogr. Phys. § 130.

sphere; this hypothesis, however, possesses a considerable portion of probability [h].

All the phenomena which we have just been considering, appear attended with brightness, and even with noise. There is one, however, which presents itself to our notice, as the result of a gentle, invisible, and noiseless force, but which is diffused over the whole of the terrestrial globe: I allude to *magnetism*. This phenomenon is very little understood as to its real nature—all that we know is reduced to this: there appears to exist a substance, or force, of some kind or other, which exercises an influence probably over all terrestrial bodies, but which is chiefly shewn as it acts upon the ore of oxidized iron, called loadstone. These substances, presented to each other, are naturally attracted at one end, and mutually repelled at the other: they constantly turn these two points, in which their magnetic action is concentrated, towards the two poles of the world: they communicate by friction, or by contact, this power to bars and needles of iron, or rather of steel; so that such a *magnetic needle* indicates by one of its points the north, and by the other south, allowing for some deviation. This phenomenon of the direction of loadstones is attempted to be explained by supposing that the globe itself is a great loadstone, which exercises its magnetic force upon all bodies more or less sensibly. We shall not enter upon the discussions to which this hypothesis must lead [i].

Magnetism.

Magnetic needle.

The earth, considered as a great magnet, has poles and an equator different from those which give to it its shape and its rotation. It is this which shews the two kinds of deviation observed in the magnetic needle.

[h] See Book xi. p. 262.

[i] Æpinus, Tentamen Theoriæ Magneticæ; les Mémoires de Coulomb, membre de l'Institut; ceux d'Euler, dans les Mémoires de Berlin, 1751, 1755, et 1757; les Mém. Suédois pour les années 1750 et 1768, avec la carte de Wilke; the Transactions of the Royal Irish Society, vol. iv. Dublin. Van Swinden, Mémoires sur l'Analogie de Electricité et du Magnétisme. Haüy, Physique, §§ 720—832.

The deviation, or the angle that the axis of the magnetic needle makes with the meridian of a place, is termed its declination. It is either west or east, and varies in different parts of the globe, at different times of the year, and even at different hours of the day. These diminutions and augmentations seem to vary periodically; and the variations are very considerable. At London the declination was 11 degrees, 15 minutes east in 1580-1; in 1657 the needle pointed directly north; in 1692 it already indicated 6 degrees of western declination; and in 1799, this declination increased to 21 degrees. In 1666, there was none at Paris; in 1795, it amounted to 22 degrees, 30 minutes towards the west. We find upon the globe a number of spots, in which there is no declination; but these *belts without declination* change their position every year. We are obliged to revise the magnetic maps every 10 or 12 years.

The diurnal oscillations are also considerable. Celsius observed a variation of 12 minutes in an hour, and from 2 to 7 minutes in the 24 hours. The experiments of Cassini, made at Paris, give the following interesting result. From 8 o'clock in the morning, until 2 in the afternoon, the direction of the needle approaches the meridian; it afterwards deviates until 9 in the evening, and remains stationary during the night. The sum of the oscillations towards the west exceeds that of the movements in a contrary direction.

Inclination of the needle.

The *inclination* consists in this: the magnetic needle, which, under the equator, generally supports itself in a horizontal equilibrium, which is given to it when placed on the pivot, deviates from its horizontal position, as it approaches the poles; one of its extremities always dips towards the pole. The greatest inclination yet mentioned is that of 82 degrees, observed by Phipps, in the latitude of 79 degrees, 44 minutes north. According to the observations of M. de Humboldt, the intensity of the magnetic forces, and above all, the inclination augments as we go from the equator to the poles, whilst the aerial traveller,

Gay Lussac, has proved, that at 21,600 feet above us, they were the same as upon the earth.

Magnetic meridians, poles, and equator.

The circle which coincides with the vertical plane, passing through the direction of the needle, is called the *magnetic meridian*: the points where all these meridians would cut each other, would be the *magnetic poles* of the earth. A great circle, upon which there is no inclination of the needle, will be the *magnetic equator*. According to the philosophical researches of the celebrated Biot [k], the magnetic equator now forms, with the terrestrial equator, an angle of 10 degrees, 58 minutes, 56 seconds; its western node upon the terrestrial equator is at 120 degrees, 2 minutes, 2 seconds, to the west of Paris, that is to say, near the Gallapago Islands, in the southern sea; consequently, its eastern node is at 59 degrees, 57 minutes, 55 seconds, to the eastward of Paris, in the Indian sea. The magnetic equator descends to the southward of the terrestrial equator in the Ethiopian Ocean, and rises to the northward in the great Eastern Ocean. Thus, a northern hemisphere projected upon the magnetic equator, would present a still greater excess of land upon the opposite aquatic hemisphere, than a northern hemisphere, already projected upon the terrestrial equator—a circumstance which, joined to the magnetic direction of several chains of islands, presents to our notice the great agency which magnetism has exerted in the formation of the globe.

Having endeavoured to explain the nature and operations of atmospheric fluids, let us proceed to consider the agitations with which this ocean of gases and vapours is affected.

[k] Mémoires de Humboldt et Biot, sur les Variations du Magnétisme terrestre à différentes latitudes. Journal de Physique, Frimaire, an. xiii. p. 211, *sqq.*

BOOK XVI.

Continuation of the Theory of Geography. Of the movements peculiar to the Atmosphere, or of Winds.

THE atmosphere experiences agitations which displace its particles in various directions, and which all depend on a single cause, an interruption of its equillibrium, the restoration of which necessarily takes place in conformity with the laws common to all fluids. A change in the temperature of a column of air, the transformation of a portion of the atmospheric gases into water, their congelation, in a word, whatever causes a vacuum, a condensation, an expansion, and consequently destroys the equilibrium subsisting among the different parts of the atmosphere, necessarily produces the rapid displacement of a mass of air, that is to say, a *wind* [a].

Definition of winds.

The velocity of winds being the circumstance most palpable to our senses, several arbitrary denominations have resulted from it, the principal of which are as follows:

Velocity of winds.

Gentle	*wind*, (a breeze,) one that traverses	10 feet in a second.
Moderate	—— (an easy gale,)	16
Strong	—— (a stiff gale,)	24
Violent,	—— (a squall,)	35
Storm,	*Slight*,	43
	Considerable,	49
	Violent,	54
Hurricane	Of the temperate zones,	60
	Of the torrid zone,	120 to 300.

[a] D'Alembert, Recherches sur le cause générale des Vents; Paris, 1754. De la Coudraye, Théorie des Vents et des Ondes, couronnée à Copenhague, en 1786. Halley, Account of the Trade-Winds and Monsoons, in the Philosophical Transactions, No. 183. Forrest, Treatise on the Monsoons, London, 1783. Dampier, Traité des Vents.

The direction of winds is not designated, like that of marine currents, by the point of the compass to which they tend, but by the point from which they come; thus, a *northerly wind* is directly contrary to a *northerly current.*

Kinds of winds.

In regard to duration, winds are distinguished as *constant* and *variable;* in regard to extent, as *general* and *partial.*

Two general and constant movements exist in the atmosphere; the one prevails in the torrid zone, and carries the air westward in respect of the earth, in a direction conformable to that of the general movement of the ocean; the other, which is principally felt in the temperate zones, carries the polar air towards the equator, and by this means produces two polar currents or effluxes, similar to those already pointed out in the ocean.

Origin of the constant easterly winds.

We shall first consider the equatorial movement of the atmosphere; that which occasions the *trade-winds*, or the constant east wind which blows in the torrid zone. The primary cause of those winds seems to be the expansion which the air undergoes from the action of heat; for the sun (which we suppose to be situated in the plane of the equator) must evidently, by its heat, rarefy the columns of air beneath it, and raise them above their level, from which they must of necessity either be dissipated in the celestial space, or sinking again by their weight, they flow towards the poles, along the higher parts of the atmosphere. At the same instant, however, a fresh quantity of air must arrive; proceeding from the polar regions, it comes to replace the air which has been rarefied at the equator. Thus two opposite currents of air will be formed; one in the higher, another in the lower strata of the atmosphere. But the real velocity impressed on each particle of air, being caused by the earth's rotation, must be smaller the nearer that particle is to the poles; and hence the circumpolar air, as it advances towards the equator, and preserves for a time its primitive velocity, must revolve more slowly than the corresponding parts of the earth; bodies situated at the earth's surface will therefore strike against it with this excess of

velocity, suffering, from its re-action, a resistance opposed to their rotatory motion; and to the observer, who imagines himself to be at rest, the air will appear to move in a direction precisely contrary to that of the rotation of the globe, in other words, from east to west.

Modifications of the constant easterly winds.

The different positions of the sun, at different seasons of the year, will produce certain modifications in those atmospheric movements. We shall indicate their general character. When the sun passes to the north, in April, May, and June, the air of our hemisphere is proportionably dilated, from the equator to the pole. It will rise therefore, and the void produced by its rarefication, in the lower strata, will be filled by a polar current. At this season, accordingly, we shall have a north wind; but in a certain latitude, suppose 30°, our north wind will encounter the general east wind; if they meet at right angles, a compound movement will result, and we shall have a north-east wind. On arriving at the summer solstice, the sun will warm every part of the northern hemisphere, more or less considerably; the heat will continue for a certain period of time; and hence in July and August we shall have fewer north-winds. But our luminary retires; the polar air is cooled and condensed anew; the equatorial atmosphere becomes more and more dilated. The general north wind will, therefore, reappear in September and October. It will go on increasing as the sun recedes from us, and approaches the winter solstice. There will be a limit, at which the condensation of the air north of the equator, and the expansion of the air to the south of it, will cease; an equilibrium more or less perfect will then reign throughout all the atmosphere.

The same phenomena, in a contrary order, must happen in the southern hemisphere. Over all the globe, therefore, we should find equatorial and polar winds of regular occurrence, if those general movements were not resisted and deflected by an infinite number of causes. Similar variations, we have seen, produce an influence on the currents of the ocean; and the atmosphere being incalcubly more subtle,

and also less homogeneous than water, we cannot wonder that it should be more sensible to the smallest impulse, and more liable to unexpected changes.

Origin of variable winds.

The inequalities of the earth's surface, and the diversity of its soils, have, no doubt, a powerful influence on the constitution of the atmosphere. At one place, mountains covered with eternal snow arise, and prevent the air from undergoing the same expansion as in valleys; at another, burning sands, forests, marshes, savannahs, are spread out, and exhale various inflammable gases; at a third, we observe large basins of water surrounded and irregularly indented by land. The air must, therefore, suffer relative and partial condensations and expansions: hence the *sea-breeze*, the *land-breeze*, the *mountain-breeze*. Those changes too will occur differently in summer and in winter, during the day and during the night. Hence the morning and the evening breezes,—those *aurae matinales*, those zephyrs, whose refreshing breath re-animates us in the warm season.

Sea and land breezes.

These alternate breezes are felt at very high latitudes, as, for example, at Bergen in Norway. The South Sea Islands, notwithstanding their small circumference, in this manner, during day-time, attract the general east wind, which is thus made to embrace them, as it were, on every side, and to blow from all points of the compass towards the central summit of the island. When night arrives, the air flows back again from the summit, towards the sea in every direction. This observation of Forster's throws great light on the theory of winds.

In the last place, chains of mountains may arrest winds in the lower regions of the atmosphere, or turn them from their direct path, and sometimes give them more impetuosity, as marine currents acquire greater force in the neighbourhood of straits and promontories. Such violent movements of the air, when arrested by an obstacle, have given particular notoriety to Cape Horn, the Cape of Good Hope, and the South Cape of Van Diemen's Land, to the Strait of Bab-el-Mandel in Arabia, and the Dragon's Mouth in America, not to mention others.

Exhalations from the soil impart their own peculiar qualities to winds. Thus, in Arabia, the *Simoom* carries much nitrous gas along with it; the *Harmattan* of Guinea much oxygen; the *Chamsin* of Egypt much azote. Winds of a peculiar quality.

The positions of the moon may exercise an influence on winds, by producing a sort of ebb and flow in the atmosphere; but we are by no means of opinion, that the immediate agency of the lunar attraction can excite such oscillations. This immediate agency, in so subtle a fluid, must be altogether transient, and, consequently, its effect almost imperceptible. The phenomenon appears rather to be caused by a re-action of the ocean on the atmosphere. Indeed, the movements of the sea must generally have an important influence on those of the air. It is chiefly from the bosom of the sea that the constituent principles of our atmosphere are unfolded; and its parts must, therefore, have a velocity proportionate to that of the aqueous particles from which they have just been disengaged. Moon's influence.

Clouds, by intercepting or condensing the sun's rays; common rain, by its cooling effect; vegetation, by absorbing great quantities of air; the decomposition of animal and vegetable substances, may all contribute to the formation of local winds.

Hurricanes appear to have an electric origin. At the moment when the electric spark unites a quantity of oxygen gas with a quantity of hydrogen, to produce a rain-storm, in all probability a considerable mass of hydrogen is consumed, and thus occasions a sudden fall of rain or hail; by which means a very large vacuum is formed, and the ambient air rushes into it, with astonishing rapidity, and sometimes in the most opposite directions. Hurricanes.

The Antilles, the Isle of France, and the Isle of Reunion, the kingdoms of Siam and China, are the countries in which hurricanes most frequently exercise their ravages. The hurricanes of Europe are not, in any way, to be compared with those of countries farther to the south; generally speaking, the former are nothing more than whirlwinds occasioned by the meeting of two opposite currents. But

in a real hurricane, all the elements seem to have combined and armed themselves for the destruction of nature. The lightnings cross each other; the thunder roars without interval; rain falls down in torrents. The velocity of the wind far exceeds that of a cannon ball, or of the powder which impels it; growing corn, vines, sugar canes, forests and houses, every thing is swept away; one might imagine the ground it had passed over was cleared and levelled. It begins in various ways; sometimes we have one little black cloud appearing on the summit of a mountain; at the instant when it seems to settle on the peak, it rushes down the declivity, unrolls itself, dilates and covers the whole horizon; at other times, the tempest advances in the shape of a fire-coloured cloud, shewing itself suddenly in a calm and serene sky [b].

Water-spouts, or syphons.

The *water spout* or *syphon*, is a no less dangerous phenomenon. Syphons are distinguished as terrestrial and marine; it were better to divide them into *air syphons* and *water syphons*. The latter usually occur in the manner we are now to describe. Underneath a dense cloud, the sea becomes agitated with violent commotions; the waves dart rapidly towards the centre of the agitated mass of water; on arriving at which, they are dispersed into aqueous vapours, and rise, whirling round in a spiral direction towards the cloud. This conical ascending column is met by another descending column, which leans towards the water, and joins with it. In many cases, the marine column is from 50 to 80 toises in diameter near its base; both columns, however, diminish towards the middle where they unite; so that here they do not extend more than three or four feet in diameter. The entire column presents itself in the shape of a hollow cylinder, or tube of glass empty within. It glides over the sea without any wind being felt; indeed several have been seen at once following different directions. When the cloud and the marine base

[b] Voigt, Magasin de Physique, vii. 36—40, (in Germ.) Comp. Encyclopédie Methodique Marine, tome iii. partie 2d, p. 813, *et seq.*

of the water-spout move with unequal velocities, the lower cone is often seen to incline sideways, or even to bend, and finally to burst in pieces. A noise is then heard like that of a cataract falling in a deep valley. Lightning frequently issues from the very bosom of the water-spout, particularly when it breaks; but no thunder is ever heard [c].

Origin of water-spouts.

Philosophers explain this phenomenon in the following manner: Two winds meet; a vortex ensues; any cloud which happens to lie between them is condensed into a conical form, and turned round with great velocity. This rotation impresses all the particles of the cloud with a centrifugal force; they are driven towards the exterior surface; a vacuum is produced within, about the axis of the cone; water or any other body lying beneath this vacuum, is carried into it by the effect of gravity striving to re-establish an equilibrium.

Having considered the general and the modifying causes of winds, let us now trace, with greater minuteness, such of those atmospherical movements as, by their regularity and extensive occurrence, are most important to geography.

Trade-wind in the Atlantic Ocean.

In the Atlantic Ocean, the general east or trade-wind prevails up to the 32d or the 28th degree of north latitude, according as the sun is in this or the other hemisphere. On the north-east coasts of America, the trade-winds extend as far as 40 degrees; a fact evidently shewing that currents in the atmosphere, like currents in the ocean, grow broader as they proceed: while, on the other hand, the east winds, like the westerly movement of the ocean, do not begin to produce a vigorous effect, till they have reached a certain distance from the eastern continent, their point of departure. The same peculiarity occurs in the Ethiopian Ocean, where the east wind extends, in like manner, some degrees farther on the coast of Brazil, than near the Cape of Good Hope. As those east winds always

[c] Voyages of Dampier, Thévenot, Le Gentil, &c. Encyclopédie Méthod. Marine, tome iii. partie 2d, p. 791. Forster, Observations on Physical Geography, p. 93, (in Germ.)

receive the impulse of the two polar atmospheric currents, at an angle approaching more or less to a right angle, they change into *north-east* in the northern hemisphere, and *south-east* in the southern hemisphere. But on approaching the coasts of America, the general east wind resumes its force, overcomes the effect of the polar currents, and follows its own direction from east to west, with more or less exactness.

Winds in the Gulf of Guinea.

On the coast of Guinea, particularly from Sierra Leone to the Isle of St. Stephen, south and south-west winds prevail over an extent of 500 leagues of shore. They turn more to the south-west and west, as we approach the land. If to this circumstance be added the fact, that, in Guinea, there sometimes occurs an east wind of extreme violence, it appears natural to regard those two movements as having a direct connexion; and the south and south-west winds will thus be nothing more than partial currents of the general trade-wind, attracted to the vast continent of Africa, where the air is prodigiously rarefied by means of the solar rays reflected from its burning sands. But as the general trade-wind must, notwithstanding, sometimes produce its effect in the interior of that continent, those great masses of air, accumulated and condensed on the central platform of Africa, will now and then make violent eruptions.

Region of calms.

On the confines of the two trade-winds, in the western ocean, between the 4th and 10th degrees of north latitude and the 330th and 365th of longitude (from Ferro,) there is a space of sea where navigators find perpetual calms, accompanied by a suffocating heat, by thunder-storms and dreadful lightning, with rains so frequent and so copious that this tract has been called the *rainy sea*. The slight winds that occur here are but sudden squalls, of short duration and little extent; so that sometimes every hour affords a different wind, which degenerates into a calm before another succeeds it.

Calms prevail equally about the common limits of the

trade-winds and variable winds; but, in these cases, they are soon destroyed by blasts and *tornadoes*. Tornadoes.

It is from observing this habitual condition of the atmosphere, that fixed methods have been laid down for sailing to and from the continent of America. In the first case, a navigator always endeavours to get southward to a latitude near the tropic, because in that quarter he is sure of finding a fresh easterly or north-easterly wind, which, joined to the prevailing current, will rapidly drive him towards the American coast. For returning to Europe, he endeavours to reach at least the 30th degree of latitude; because it is here that the winds first become variable, though still more frequently they blow from south-west.

In the *Great Ocean*, or Pacific Sea, we again find the general movement of the atmosphere from east to west, modified by the two polar currents. The vast extent of this sea allows the atmosphere to unfold its natural movements in a regular manner. The north-east and the south-east winds are here so steady and strong, that, if at Panama, in place of an isthmus, there were a strait, the voyage to China would be accomplished much sooner by sailing westward than by sailing eastward. As those movements set out from America and the Andes mountain-chain, they are more feeble and circumscribed on the coast of America, where they begin, than near or even within the tropics. On the opposite coasts of Asia and the regions to the south, they extend as far as the fortieth parallel In sailing from Acapulco to the Philippines, the Spaniards simply allow themselves to be carried forward by the winds and currents, which drive them in a straight line, and very speedily, to their place of destination; and this is the reason why, though navigating that ocean so long, they have discovered so very few of those southern regions, from which they were frequently at no great distance. In returning to Mexico, they ascend as far as Japan, and then direct their course to the north-west coast of California. This great extent of the trade-winds must be attributed to the weakness of the polar currents, aërial as well as marine. Trade-winds of the Pacific.

while it is the superior strength of the south polar currents which causes south winds to prevail along the coast of Peru.

Monsoons, or half-yearly winds of India.

It is in the Indian Ocean alone that the famous *monsoons*, or half yearly winds, seem to destroy the uniformity of the general atmospheric movement. No doubt, however, they might be made to accord with it, provided we know all the circumstances which influence them. We exhibit the facts in the first place. From the 10th degree of south latitude to the tropic of Capricorn, and beyond it, the general east or south-east trade wind prevails over all the Indian Ocean, sometimes in summer extending as far as the 2d and 3d degrees of south latitude. On this side the 10th degree, we first meet with the *monsoons* [d] or periodical half yearly winds. North of the equator, from April to October, a violent *south-west* wind prevails, accompanied with tempests, storms, and rain; while a soft and pleasant *north-east* wind blows during the other six months. Between the second and twelfth parallels of south latitude, the winds blow generally from *north-west* during the winter six months, from *south-west* in summer [e].

During winter, then, the constitution of the atmosphere exhibits the following principal circumstances: North-east winds north of the line; north-west winds south of it, to the 10th parallel; and finally, the east and south-east trade-winds. In *summer*, the phenomena are less contradictory: South-west winds from the 10th parallel to the northern limits; trade-winds south of the 10th parallel.

Varieties in the Monsoons.

These general tendencies are subject to variations, depending on the figure and elevation of coasts, on straits, and currents of the sea. The north-west and south-west monsoons are weaker and more variable in the Bay of Bengal, more steady and violent in the gulf of Arabia. Both those monsoons grow broader to the west, ranging in this direction over the whole tract of sea that lies between Af-

[d] From a Malay word, *moussin*, signifying *season*.

[e] Moore's Practical Navigation, 12th edit. London, 1796, p. 124, *et seq.*

rica and Madagascar. In the seas extending between China, the kingdom of Siam, Sumatra, and the equator, those monsoons are felt likewise; but here, excepting local variations, they are almost entirely *north* and *south*. They extend as far as the Philippine Islands, and though with much inconstancy, even to Japan. Between the equator, the island of Java, and New Guinea, the monsoons are nearly similar to those of the Chinese Sea, in regard to their direction, which merely varies a little to the north-west in the north monsoon, and a little to the south-west in the south monsoon. But they do not begin till six weeks after those of the Chinese Seas.

How the monsoons change.

Some other striking circumstances still remain to be noticed. The monsoons do not change, or, as sailors express it, do not break, of a sudden. Their change, which usually takes place fifteen days or four weeks *after the equinoxes*, is announced by the decay of the existing monsoon, by calms and squalls in rapid succession, by storms, water-spouts, tornadoes, and by Indian hurricanes, called *taifouns*, particularly terrible from the explosions of electric matter accumulated by the monsoon. The beginnings of the subsequent monsoon are, at first, liable to variations, till finally it establishes an absolute dominion.

Double winds.

Navigators assert, that, on quitting the region where a monsoon prevails, one is sure, in ordinary circumstances, to fall in with a very strong and impetuous wind, blowing from a quarter directly opposite. They must naturally have observed this phenomenon with much care, since the calms and whirlwinds it occasions are productive of great danger. It can hardly be explained, except by admitting, with Halley, the existence of two currents,—one above, composed of warm and rarified air; another below, composed of the column of cold and condensed air. This hypothesis will become almost a settled truth, if we observe how small is the elevation to which the monsoon extends—a fact clearly exhibited in the peninsula on this side the Ganges, where the monsoons are arrested for several months by the mountain chain of the Gauts, (not certainly of extraordinary height;)

so that the coast of Coromandel, and that of Malabar, have always their dry and their rainy seasons, at opposite periods of the year.

According to the preceding description, it is the *south-west monsoon* alone which presents any phenomena directly contrary to the general movement of the atmosphere; for the north-east monsoon is in conformity with it, and the north-west wind south of the line seems not to be altogether constant, and may perhaps arise from nothing more than a compound movement, or a higher current of air. What then is the origin of this half-yearly wind, which in summer blows from south and south-west, over all the Indian ocean? The sagacity of physical geographers[f] has long been exercised by this question. We give the explanation of which Halley laid the ground-work, and which appears to us the most plausible.

General explanation of the monsoons.

The monsoons always change some time after the equinoxes; they constantly blow towards that hemisphere in which the sun is found. The action of this luminary on the atmosphere, is, therefore, plainly one of their causes. When its rays, reflected from the mountains of Thibet, scorching the plains of Bengal, and the valleys of the kingdom of Siam, rarefy and dissipate the atmosphere, the cold air becomes violently attracted from the regions about the south pole. The sun's action is seconded by the marine current, which proceeds from the south polar seas to those of India. This current must bring with it a column of vapours, continually disengaging themselves from its surface. The absence of a northern marine current must farther be added; we can even imagine, that the mountains of Thibet, and the whole central platform of Asia, may arrest and preserve the cold air, which would otherwise proceed from Siberia towards India.

But why does not this polar wind prevail south of the equator also? For the same reason which renders the

[f] Deluc, Modifications de l'Atmosphère, No. 730. Muschenbroek, Essai de Physique, ii. 879

aquatic polar current inconsiderable there. The general movement of the ocean being here opposed by no obstacle, has too much force to be modified by the polar current. A similar result happens in the atmosphere, at all times intimately connected with the ocean, which feeds and modifies it. But on leaving New Holland between us and the Pacific Ocean, the general movement of the Indian sea must evidently be more and more abandoned to its individual force, and that force must soon be overcome by the polar current, which, after being long deflected or concealed by the general movement of the ocean, now re-appears in all its energy. The polar column of water now fills the atmosphere with cold particles, which, by their gravity, determine the whole atmospheric mass to flow towards the equator, more strongly and more directly than it would have flowed otherwise. It is possible, moreover, that higher currents may exist in the atmosphere, and descend towards the earth at the time when the monsoons commence.

Explanation of particular circumstances.

On the west side, the mountains of Lupata in Africa, and those of Madagascar, may, or rather must concur in furnishing their cloudy and stormy air to the south-west monsoon, which, from this circumstance, begins here, in the channel of Mozambique. It is possible that mountains in the interior of New Holland may exert a similar influence on the east side.

When the sun has passed into the southern hemisphere, the monsoon alters its direction; the mass of air which had been accumulated during summer on the central platform of Asia, now bestirs itself, and moves towards the regions south of the equator, where the atmosphere has been dilated and dissipated by the solar heat. Over most part of the Indian ocean, this monsoon proceeds from the north-east, because the central platform lies to the north-east. On the other hand, as the seas of China, of Borneo, of New Guinea, of Java, have the centre of Asia to the north and north-west, the monsoon comes to them from those points. It arrives in a slow progression, in consequence of the many

islands whose elevated summits arrest and turn it aside The north-east monsoon is mild and agreeable, because the mass of air, condensed on the central platform of Asia during summer, having originally passed through the torrid zone, and afterwards remained exposed to the sun's action about the time of solstice, it has thereby lost the cold and the cloudiness which otherwise it might have acquired from contact with the Siberian atmosphere. It seems possible that this north-east monsoon may fall in with a remnant of the preceding monsoon, about the second or third degree of south latitude; a remnant, which is perhaps maintained in existence by the mountains of Africa, Madagascar, and New Holland, since the cold air of those mountains is not solicited to flow towards the south pole, and has no outlet but towards the equator. From this direct rencounter of the old and the new monsoon, a compound movement would result, which might produce those north-west winds so common between the equator and the tenth southern parallel, during the whole continuance of the north-east monsoon.

Both monsoons are more powerful in the Arabic Gulf, because this strait and shallow piece of water has no currents in it but such as are superficial, and therefore unable to resist the action of the winds.

General conclusion.

All the irregularities displayed by winds pertaining to a place or a region of the globe, are thus nothing more than combined effects resulting from the general atmospheric currents, from partial interruptions of them, from the sun's apparent motion, and the arrangement of mountains.

The reader who has followed us through those wide but indispensable details, may perhaps desire that we should recompense him by again pourtraying the useful or agreeable effects, of which the winds, whose paths we have just been tracing, are productive. Shall we stop to repeat observations so familiar? The winds, it is well known, purify our atmosphere, by keeping up a perpetual agitation in it; they dissipate the miasmata exhaled from marshes and stagnant water; they raise and transport the clouds destined to fertilize the ground by means of rain. Millions

Utility and pleasures derived from winds.

of seeds, furnished with their little pinions, ride upon the wings of the wind, and spread afar the empire of vegetation. The ingenuity of man has made a lever of the winds, which, when applied to machinery, spares him an immensity of toil. If the ocean is the highway of our globe, winds are the indefatigable coursers which rapidly transport our ships from pole to pole. Considering winds merely in a picturesque point of view, how many enjoyments do they procure to a lover of the great spectacle of nature—above all, to the inhabitant of mountains! Sometimes they spread over every valley a curtain of clouds, which shews the summits of the far distant Alps like so many islands scattered on the surface of an ocean; sometimes partially drawing this curtain aside, they open to us all at once the most astonishing prospects, in which the brightest sunshine forms a happy contrast with the contiguous shades. It is to storms of wind, that the painter and the traveller are indebted for the most extraordinary scenes which can meet their view. In the evenings of summer, and still more of autumn, it is the winds which, accumulating and marshalling their long trains of clouds, create and destroy before us those fugitive landscapes, those aërial mountains, which are tinged by the fires of the setting sun.

The atmosphere undergoes various other modifications in respect of its local temperature, or of *physical climate*. They will form the subject of our next book.

BOOK XVII.

Continuation of the Theory of Geography. Of the Local Temperature of the Atmosphere, or of Physical Climates.

In no department of geography have authority and preconceived opinions been permitted to prevail more generally than in that which treats of the causes of physical climates. The sun was long considered as the only source of those varieties of temperature which we experience in the different regions of the earth. The influence ascribed to winds was determined only according to some local observations which had been made by Hippocrates in Greece, or in the neighbouring countries. That this branch of physics may be thoroughly investigated, it is requisite for civilized nations not only to dispatch travellers to the neighbourhood of the poles and the equator, but also to form permanent establishments in these quarters of the globe. It is by uniting together and arranging, under general points of view, the results of particular local observations, that we shall endeavour to trace a sketch of *climatology*, in some measure corresponding to the present state of the other sciences.

Physical climate.

Physical climate comprehends the degree of heat and cold, the drought, the humidity, and the salubrity, which occur in any given region of the earth.

Its causes.

The causes of physical climate are *nine* in number:

1*st*, The action of the sun upon the atmosphere. 2*d*, The interior temperature of the globe. 3*d*, The elevation of the earth above the level of the ocean. 4*th*, The general inclination of the surface, and its local exposure. 5*th*, The position of its mountains relatively to the cardinal

points. *6th*, The neighbourhood of great seas, and their relative situation. *7th*, The geological nature of the soil. *8th*, The degree of cultivation and of population at which a country has arrived. *9th*, The prevalent winds.

The air does not appear to acquire immediately, by the passage of the solar rays, a considerable degree of heat. It is this which proves the successive coldness of the different strata of air which is observed upon all mountains [a].

Sensible and latent heat.

The distinction between *sensible heat*, which warms the particles, and *latent heat*, which only dilates them [b], makes us imagine that the superior air, more disengaged from vapours, and less compressed, must allow the calorific rays to pass more freely; and that, on the contrary, the more the air is condensed, the more will the rays be stopped in their course, and repelled, and reflected; in various directions the shock of the two fluids will thus be more forcible; and it is probably a similar shock that causes the disengagement of latent caloric, which is the principal cause of the sensible heat of our atmosphere.

Reflection of caloric.

But what chiefly contributes to warm the lower regions of the air, is the reflection of the rays which strike against the ground, and which, thrown back again towards the atmosphere, stop in the inferior part of it, and are confined in the midst of the watery vapours with which it is loaded. This reflection necessarily accumulates the heat in the regions nearest to the surface of the earth. We cannot here explain the theory of caloric considered as a radiant body, a theory which has been recently developed [c]; but it is sufficient for our purpose to observe that extraordinary degree of heat which often exists on two sides of the same mountain, whilst the neighbouring plain is but moderately warmed.

The degree of immediate solar heat is determined by

[a] Delue, Modifications de l'Atmosphère, ii. § 797, *sqq.*

[b] Laplace et Lavoisier, Mémoire sur le Calorique latent, dans les Mémoires de l'Academie des Sciences, 1780, p. 388.

[c] Prevost, Théorie du calorique rayonnant, Genève, 1809.

four causes[d]. The first is the distance of the sun from the earth. If we take the mean distance equal to 10,000, the distance at the summer solstice is equal to 10,166, and at the winter solstice to 9,834; the proportion is nearly as 30 to 29. The quantity of rays falling upon the same plane, being inversely as the squares of the distances, their proportion will be as 841 to 900, or as 1 to $1\frac{1}{17}$. Thus the quantity of solar rays which the globe receives in winter is greater than that which it receives in summer. The second cause which we have to consider is the direction more or less oblique, in which the rays strike the earth, and which depends upon the height of the sun in the ecliptic. The more directly the rays fall the more force they have, and, at the same time, the greater is the number falling upon a given space.

Fatio, in considering the perpendicularity of the rays, which gives them a great force, computes, that, independently of all other causes, the heat of summer should be to that of winter as 9 to 1. But these calculations suppose the surface of the earth to be exactly spherical, without the least local declivity. The third circumstance to consider is the length of the day, or the length of that semi-diurnal arc which the sun describes. The continuity augments the effect, and the short nights allow only a small quantity of the acquired heat to evaporate. The fourth and last cause, which modifies the solar heat, is the refraction which the rays experience in passing more or less through the different strata of the atmosphere. Bouguer has calculated, that, taking 10,000 rays, 8,123 of them arrive at a given point, if they come perpendicularly, 7,024, if the angle of direction is 50 degrees, 2,831 if it is seven degrees, and only 5 if the direction is horizontal.

The solar heat, distributed according to these four principles, would be entirely different from that which we actually experience. We should have in the summer sol-

[d] Mairan, Mém. de l'Academie des Sciences, 1719 et 1765. Bouguer sur la Gradation de la Lumière. Bergmann, Géog. Physique, § 110.

stice under the line, 20 degrees of Reaumur's thermometer; at Paris, 36; under the polar circle, 68; and under the 74th parallel of latitude, we should find the terrible heat of 80 degrees of Reaumur. It would then diminish towards the poles. In the winter solstice, the cold would be equally distributed in a manner perfectly contrary to experience. We are therefore certain that the direct and immediate action of the rays of the sun does not of itself determine physical climates.

Internal heat of the globe.

Some persons have sought for the cause of climates in the *internal heat* of the globe, which generally appears to be about 10 degrees of Reaumur above zero.

Central fire.

That heat is not the effect of a central fire. Such a fire might, without doubt, exist in the bosom of the globe, as there are cavities filled with air, but it would act more powerfully, and with greater uniformity. The beneficial influence of it would be felt towards the poles, as well as under the equator. All the deep springs would be hot. Romé de l'Isle, in his work upon the heat of the globe, has refuted all the false reasonings by which Buffon and Bailly had deceived themselves. We shall form a juster conception of the internal temperature of the globe, if we regard it as the result of the different degrees of heat which it may have acquired from the successive action of the sun, and which are accumulating in the course of ages, as far as the density of the globe admits of it, and the force of the solar rays is adequate to the production of such an effect. The globe having once acquired this depth of heat, which is uniformly diffused through all its parts, the variable temperature of our summers and winters can no longer produce a change in its interior. But if we suppose some local fermentations in the interior, these might influence and modify the external temperature. It is possible, too, that some kinds of soils transmit with more facility than others, the internal heat. Finally, observations having shewn that the internal temperature of lakes and of seas is much below that of continents; the inference is, that in summer, the atmosphere, which is in contact with

these masses of water, must always be less heated than that portion of it which is contiguous to the earth[c].

Elevation of the ground.

With the elevation of the land, cold increases in a very rapid progression. It is superfluous to produce examples of this, who does not know that winter continues to reign on the Alps and the Pyrennees, while the flowers of spring are covering the plains of northern France? This beneficent appointment of nature, considerably increases the number of habitable countries in the torrid zone. It is probable, that at the back of the flat burning coasts of Guinea, there exist in the centre of Africa, countries which enjoy a delightful temperature; as we see the vernal valley of Quito, situate under the same latitude with those destructive coasts of French Guyana, where the humid heat constantly cherishes the seeds of disease. On the other hand, it is the continued elevation of the ground, which, in the central part of Asia, extends the cold regions to the 35th parallel of latitude, so that in ascending from Bengal to Thibet, we imagine ourselves in a few days transported from the equator to the pole.

General and local aspects.

The general *aspect* should be distinguished from the local aspect. The west of France, for example, has a general western aspect; and notwithstanding this, the valley of Allier is exposed to the north; that of Mayenne to the south; that of Ouest in Brittany to the south-east. Thus, the general declivity of a country, large in itself, does not exclude the most opposite local declivities. It may, however, be admitted as a general principle, that the positive sum of all the local aspects is in the same direction as the general aspect. This principle can be applied only to spaces of great extent; for example, the entire tract of country through which a river flows.

Effects of aspect.

Every one knows of what effect, as to temperature, is the exposure of a soil relatively to the sun. A hill, inclined 45 degrees towards the south, when the sun is ele-

[c] See the authors quoted by Delamétherie, Théorie de la Terre, iii. sect. 755, 756, &c. &c.

vated 45 degrees, receives the solar rays perpendicularly, whilst upon a plain, the same rays strike the soil under an angle of 45 degrees, that is, with one quarter less of force; and a hill inclined 45 degrees to the north, will be struck by the solar rays in a horizontal direction, which makes them glide along its surface. If the ground is still more inclined to the north, it will receive no rays, and will remain always in the shade. These differences, which are easily perceptible in hilly countries, are extreme in regions covered with high mountains. It is thus, that in the Valais, we see the Alps on one side covered with eternal ice, whilst vineyards and orchards adorn the opposite hills with all the charms of fertility.

Effects of the course of the sun.

There is still another circumstance to be observed. The angle of incidence of the rays of the sun is determined for any given moment of the day, by the exposure of the land, but it varies also with the diurnal course of the sun. The hill, which in the morning received the solar rays under a direct angle, receives them more obliquely at noon, and perhaps the rays in the afternoon will merely glide over the surface of the ground. The case is precisely the reverse with hills exposed to the west. This is attended with some very remarkable consequences, which we are about to explain.

West and eastern aspects.

Every *western exposure* (from south-west to north-west) ought to be warmer than the corresponding eastern exposure, all other things being equal—for the rays of the morning, which directly strike the hills exposed to the east, have to counteract the cold which has accumulated there during the night. When the atmosphere, in the afternoon, shall have reached its greatest degree of warmth, the solar rays will no longer serve to concentrate this mass of heat upon soils lying towards the east; for they will fall only obliquely. On the contrary, those hills which incline towards the west, have been already provided with heat during the whole morning; and as soon as the solar rays strike them in a direct manner, they collect and concentrate all the caloric of the atmosphere, without encoun-

tering any obstacle. Every thing, on the contrary, will concur in promoting their action.

Warmest aspect.

Without stopping to give more detailed explanations, we shall only remark, that according to this principle, *south-south-west* and *south-west* situations are the warmest of all; whilst, on the contrary, those of the *north-east* are the coldest. It is scarcely necessary to observe, that we speak here only of the *Northern Hemisphere*, and that we leave out of view all local and temporary circumstances.

As a moderate degree of cold is favourable to health, and as, under the latitude of Greece, any degree of cold to which they were ordinarily exposed, may rather be looked upon as refreshing than disagreeable, it is clear that Hippocrates was right in recommending eastern situations with regard to salubrity [f]. But is it not contrary to good sense to apply the same principle to climates much nearer the Pole, where the cold is regarded with apprehension, and where the heat, generally more moderate, brings with it none of those epidemic maladies of which Hippocrates speaks. There are so many circumstances which combine to render a climate salubrious or unhealthy, pleasant or inhospitable, that the attempt would be extremely injudicious to characterise climates *solely* according to general or local exposures.

Exposures parallel to the different parts of the day.

If we consider exposures only by themselves, and without reference to other circumstances, we may, with Hippocrates, compare the eastern one to Spring, those of the south to Summer, those of the west to Autumn, and those of the north to Winter—for although it is true that the constitution most common to climates under these exposures answers to that of the seasons which they resemble, yet a more exact and more intelligible comparison would be one with the different *divisions of the day*. The most severe cold is felt early in the morning; this division corresponds to the north-east exposure, which is the coldest; the heat augments until three in the afternoon. In like manner,

[f] Hippocrate, Traité des Airs, des Eaux, et des Lieux.

exposures become always more favourable to heat, till we come to the south-west. Evening and midnight follow, corresponding to western and northern exposures.

In considering the climates peculiar to each country, in the subsequent volumes of this work, we shall see these general observations confirmed by a great number of examples.

Positions of Mountains.

The *position of mountains* is not always essentially connected with declivities of ground, since there are some mountainous plateaux or upland plains, which (at least as to a portion of their extent) have no general declivity, as in Mongolia, in Thibet—and since, on the other hand, we find countries which incline on several sides, without their most elevated parts being furnished with real mountains, as, for example, the centre of European Russia.

Mountains act upon climates in two ways—they attract the vapours suspended in the air; these vapours, by their condensation, produce clouds and fogs, which generally conceal the summits from our view. Often, also, these assemblages of watery substances, which the winds waft in every direction, are stopped in their devious course by chains of mountains, in the elevated valleys of which, they continue to accumulate. These effects are still more sensibly felt, when a chain of mountains is crowned with extensive forests. They add to the elevation of the mountain, they block up its passages, and they furnish, above all, inexhaustible nourishment to the running waters. The destruction of forests may sometimes prove a blessing to a country, by procuring a freer circulation of air—but, carried too far, it becomes a scourge which may desolate whole regions. We have a sad example of this in the Cape de Verde islands, not to mention others of a less striking character. It is the destruction of the forests, and not a supposed *cooling of the globe*, which has rendered the southern part of Iceland more accessible to the dreadful cold which is too often produced by those masses of floating ice which are intercepted and detained by its northern coasts. Although mountains cannot prevent the general motions of

Shelter given by forests.

the atmosphere from taking place, they may, however, by stopping them in part, render particular winds more or less frequent throughout a certain extent of country.

There cannot be a doubt that the Alps do contribute in securing to Italy its delightful and happy climate, its perpetual spring, and its double harvests.

Effect of the absence of mountains.

Examples of climates, rendered colder by the position of mountains, are frequent enough. If central and southern Russia are exposed to colds disproportionate to their latitude, and to their exposure, which is in a great measure southern, it is owing, amongst other causes, to the want of a chain of mountains to the north, which might weaken the action of the chilling icy winds that blow from the White Sea and the Uralian mountains. Siberia is in a different, and still more unfavourable predicament. It slopes to the north, and consequently lies open to winds from the Frozen Sea; at the same time, its great inclination is, on the south side, crowned by the Altai mountains, which, while they hinder the cold winds from getting vent, and passing farther away, intercept also the warm breezes of Southern Asia.

Temperature of valleys.

The shelter from winds which is afforded by mountains, may sometimes become hurtful from excess. Thus we find the heat prove insupportable in those valleys, which in summer concentrate and strongly reflect the rays of the sun. When valleys are extensive and wide, when they present a considerable declivity for the flowing of water, and afford free access to winds from the north, the temperature may then be dry and cold, as in the Champsaur described by Villar. The inhabitants of such places will have good complexions, and enjoy a sound state of health.

Unwholesome valleys.

In valleys which are low, narrow, and hollow, and which receive dry winds only very obliquely, torrents of water and the rains find no vent, the surface becomes marshy, the air does not circulate, and dampness and fogs perpetually prevail. It is in such places that we meet with beings feeble, indolent, and stupid, that are called *cretins:* they become deaf, dumb, and almost blind; they remain insensible to all im-

pressions, except sensual appetites; if we strike them, they testify no sensation; and they appear to be excited by no wants. Their dangling arms, their gaping mouths, their necks swollen and pendant, their cadaverous colour, indicate the lowest state of human degradation, and of animal degeneracy. The chilling damp which constantly broods over these countries, except when it is exchanged for the warm and equally relaxing vapours of summer, may be regarded as the true cause of the goitre and of *Crctinism*. These maladies bear a great analogy, in their cause and principal effects, to the swellings, the articular tumours, and the imbecility of the effeminate Scythians mentioned by Hippocrates. Fodéré, who purposely visited the valley of Aosta and Maurienne, where cases of goitres and mental imbecility chiefly occur, remarks, that they appear only in the centre of the valleys of the Alps, and that even there they are confined to the narrowest part of the valley, which ceases to produce them as it widens towards the summit of the mountains, where brisker and drier air prevails, in which the inhabitants enjoy health.

These maladies are to be found in the Bas Vallais, at the base of the Pyrenees and Apennines, and in some of the vallies of Dauphiny and Upper Provence. The sallow inhabitants, which we see in several humid districts of America, the white Negroes of the Ethiopian and Madagascar mountains, and the piebald Negroes, appear all of them to be a species of cretins in a greater or less state of degeneracy. Zimmerman attributes to the suffocating heats, which are felt in certain deep valleys of Switzerland, the instances of madness which are so common in these places; and he states, that the inhabitants of these defiles are obliged, during summer, to send away their children to the neighbouring mountains, for the preservation of their memory and reason[g].

The neighbourhood of the sea moderates the excess of temperature. In hot climates, the maritime regions are not Effects of the neighbourhood of the sea.

[g] See the articles Switzerland, Carinthia, &c. in this Work.

so warm as the centre of the plains. In high latitudes, the coasts and the islands are less cold than the interior of the continents. In the mountains of Norway, so intense is the cold, that it has sometimes proved fatal to the Swedish armies; the dead bodies have been found lying rank and file; at the same time, the coasts of the country enjoy a very mild climate. The port of Bergen does not freeze so often as the Seine. Laurels, fig-trees, myrtles, and pomegranates, which cannot subsist in the centre of France, grow naturally in abundance at Brest [h]. The temperatures of the different seasons also approach nearer each other in the neighbourhood of the sea. At Plymouth, although the mean heat of the year is, on the whole, a little less than that of Paris, the winter months are much less cold. The thermometer never sunk lower in the time of Huxham than ten, or ten below zero, nor rose higher than 21.2 on the scale of Reaumur.

Influence arising from the nature of the soil.

The internal nature of the soil must have an influence on climate in a variety of ways. All grounds are not heated equally soon. One soil quickly parts with its acquired heat, while another retains it for a long time. Exhalations, which vary according to the nature of the soil, rise into the atmosphere, and become identified with it. Clayey grounds, and those which are impregnated with salt, cool the atmosphere; extensive accumulations, when they are dry, augment the heat. It is supposed, for example, that the severe cold, and the unwholesome air, which prevail in the governments of Astracan and Orenburg, partly arise from the saline nature of the soil; while several provinces in France owe in part their dry and salubrious temperature to this, that their soil is sandy, calcareous, and in general light; ground which is stony and barren, emits fewest vapours. The contrary may be said of marshy soils; grounds of this description, and even sands impregnated by moisture, diminish the heat; and as the waters there are for the most

[h] See the articles France and Russia.

part stagnant, the duration of the frosts is prolonged without bringing in return a sky serene and unobscured by noxious fogs. This is the reason why the winter in Holland, under 52 degrees of latitude, is often more disagreeable than that of the Danish islands under the 55th parallel.

The effect of marshes, in hot countries, is still more fatal, for they ferment and evolve a great quantity of putrid effluvia; it is to these that the eastern coasts of Africa, and some parts of America, owe their pestilential climate[1].

Different aspect of the sky.

In every country, the sky has a different aspect. The azure arch, which, by an optical illusion, on every side limits our view, seems to be lower in England than it is in France. In vain does the Italian, upon the borders of the Seine, look for that pure, serene, and boundless sky, that atmosphere of clear blue, or of vivid red, which so much contributed to inspire a Raphael and Correggio.

But even the Italian sky is cloudy, in comparison of that which, in summer, canopies the blissful islands of the Pacific Ocean, that paradise of the torrid zone. It is to the different degrees of the rarefaction of the air, as well as the nature of terrestrial exhalations, that we must attribute these different appearances of the sky, on which the beauty of a climate partly depends.

Influence of the labours of man.

Man exercises a slow but powerful influence upon the temperature of the air. Without cultivation, few climates would be salubrious and agreeable. Let us contemplate a desert country; the rivers, abandoned to themselves, become choaked, and overflow; and their waters serve only to form pestilential marshes. A labyrinth of thickets and of brambles overspreads the most fertile hills. In the meadows, the unsightly wild mushroom, and the useless moss, choke the nutritious herbs; forests become impenetrable to the rays of the sun; no wind disperses the putrid exhalations of the trees which have fallen under the pressure of

[1] See the description of Africa, vol. iii.

age; the soil, excluded from the genial and purifying warmth of the air, exhales nothing but poisons; and an atmosphere of death gathers over the whole country. But what do not industry and perseverance accomplish? The marshes are drained; the rivers flow in their disencumbered channels; the axe and the fire clear away the forests; the earth, furrowed by the plough, is opened to the rays of the sun and the influence of the wind; the air, the soil, and the waters, acquire by degrees a character of salubrity; and vanquished nature yields its empire to man, who thus creates a country for himself.

Inconveniencies of new countries.

The cultivation, however, of a new country, is often attended by most disastrous consequences, which ought not always to be imputed to the improvidence of colonists. The new soil, the moment that it is broken up by the plough, and penetrated by the rays of the sun, must necessarily undergo a strong evaporation, and its exhalations, which are not always of a harmless kind, little elevated in the air, are condensed by the cold which still continues to be sharp, particularly during the night. Hence arise those epidemic maladies which ravage colonies newly established. The destruction of forests, especially when carried too far, is followed by pernicious effects. In the Cape de Verde Islands, it is the burning of the forests which has dried up the springs, and rendered the atmosphere sultry[k]. Persia, Italy, Greece, and many other countries, have thus been deprived of their delightful temperature. The cutting down of the forests which once covered the Pyrenees, has rendered the air very unwholesome in the valley of Azun, in the department of the Eastern Pyrenees, because the absence of that barrier now permits a free passage to the southern winds. Similar complaints are made in Castile and Arragon.

Influence of predominant winds.

The *predominant winds* of every country variously modify the united influence of all the elements which constitute physical climate, and which we have just been

[k] See Africa, Cape de Verd Islands, vol. iii.

considering. But the nature, the direction, and the intensity of the winds, depend upon general and local exposure, the neighbourhood of seas, the elevation of mountains, and other circumstances. Thus the causes of climate form together a circle of which we can point out neither the first link nor the last. We ought not to characterize the physical nature of winds in a general manner, according to the points of the compass from which they blow. Hippocrates made use of this method, but confined his observations to a small part of the globe. But we should only injure the reputation of this great man by attempting to apply his local maxims as general rules.

General principles as to the nature of winds.

All the variations of the winds depend upon the equilibrium of the atmosphere. Hence it follows, that the heat of one climate, and the cold of another, exercise a continual influence upon each other. The northern parts of a great continent will sometimes send forth their cold air towards the southern parts; and sometimes they will receive warm air in return. The great facility with which the atmosphere is put in motion, does not permit us to limit these facts to particular places: the whole of the heat and cold which surrounds the globe, is in a state of constant and universal flux and reflux. We may, therefore, lay down the following principles. The heat of the torrid zone, and the polar cold, balance each other; and upon the fluctuation of their equilibrium depend the variations of heat and cold, which are felt in the temperate zones. All winds, in the temperate zone, coming from the neighbouring pole, are cold; and all winds from the equator are hot, with some exceptions occasioned by local circumstances. Thus the southern wind cools and refreshes the environs of the Cape of Good Hope, whilst the northern wind has the same effect upon Europe. A land wind, if it passes over plains very elevated and open, is almost always cold and dry in the temperate zones. But between the tropics, if it blows over plains little elevated, and covered with burning sands, it must be dry and warm. The winds which arise on mountains, are not more conformable to any general rule;

for there are some mountains covered with ice, whilst upon others there prevails a remarkable dampness: the winds from these, therefore, will possess different properties. As to winds from the sea, they are, almost without exception, damp, and charged with fogs and saline vapours; and as the air they bring with them is always either hotter or colder than the air upon the land, they constantly occasion that kind of decomposition of atmospheric vapours, which produces rain. It follows, then, that every country of the temperate zone which is separated from the equator only by a great extent of contiguous land, has necessarily the air more habitually hot, than that country which has vast seas flowing between it and the torrid zone. On the contrary, the countries of the temperate zones, which have extensive tracts of land between them and the neighbouring pole, and which are separated from the equator by seas, will have a climate habitually colder than other countries under the same latitude, but under another combination of local circumstances.

Consequences of these principles.

If we apply these different principles to the northern part of the old continent, we shall see that the enormous diminution of heat which we observe as we advance towards the East, under the same latitudes, is in a great measure owing to the form and position of that mass of earth. The western part derives warmth from being in the neighbourhood of Africa, which, like an immense furnace, distributes its heat to Arabia, to Turkey in Asia, and to Europe. On the contrary, Asia, in its north-east extremities, experiences extreme cold; partly, because on that side it has no land extending towards the equator. If Greenland, under the 60th parallel, notwithstanding its southern exposure, and the neighbourhood of the sea, has a much more rigorous climate than Lapland under the 72d parallel, with a northern exposure, what other reason can be assigned for this phenomenon, than the separation of Lapland from the arctic region by means of a vast ocean, whilst Greenland, gradually widening, extends probably towards the pole, or at least towards the 82d degree of latitude? North America

Diminution of heat towards the east.

has few tracts of land situate in the torrid zone; it has little communication with South America, and it stretches out probably to the north of Baffin's Bay towards Greenland. This quarter of the world does not present so great a difference of climate as Europe.

East and west coasts in the torrid zone.

There results also from our principles, a general consequence as to the countries of the torrid zone. The trade-winds, by blowing continually from the east over the sea, contribute to render all the maritime coasts on the eastern side colder than those coasts which look to the west. On the other hand, the more a continent extends from east to west, the more those winds are heated by passing over the lands scorched by the sun. This is the reason why the Antilles, or Caribbee Islands, enjoy so moderate a temperature, whilst Senegambia is afflicted with the most overpowering heat of which we have any example. Congo also is warmer than Zanguebar. If the mountains of Peru have a colder climate than Brazil, it is because the elevation of ground, or any other local circumstance, may often have sufficient influence to neutralize the effect of a general cause. Such are the different causes which concur in forming that general constitution of the atmosphere which is termed climate. We may perceive that the results of so many different causes do not easily admit of classification. Hippocrates, indeed, has attempted this with regard to Greece. He takes for the basis of his arrangement, *exposure* and *winds*. But it is easy to prove, that his four climates, though actually existing in the places where he observed them, are not to be found in all the regions of the globe, to which his commentators, possessing little of his genius, wish to extend his system.

Examination of the climates of Hippocrates.

Hippocrates commences his treatise upon air, water, and situations, by an explanation of the object which he has in view. "It is necessary," says he, "for a physician, when entering a city of which he knows nothing, to examine its exposure, the predominant winds, the seasons, the nature and elevation of the soil, the quality of the waters of which the inhabitants make use, and the kind of life they follow.

Now," continues he, "I am about to shew how we ought to investigate and ascertain each of these circumstances[l]."

Is it not clear, according to this phrase, so vaguely rendered by all translators, that the intention of Hippocrates was not to compose a *treatise* upon physical climates, the materials for which were not collected together in his time, but that he meant nothing more by detailing his own local observations than to point out to his successors the path to be followed for the purpose of making new ones? This modest intention of the author has been overlooked, or at least but indistinctly pointed out. His work contains observations highly interesting, but confined exclusively to the countries which extend from the Sea of Azof to the mouth of the Nile, and from the borders of the Euphrates to the shores of Sicily; but these local observations, by being made general, have been converted into false and dangerous ones. We shall here produce some examples: Hippocrates represents to us "countries entirely exposed to the hot winds of the south, as necessarily abounding in brackish and unwholesome waters; for these waters, in general, not being deep, are warmed in summer, and cooled in winter." He then describes the maladies which will prevail in such regions: "The inhabitants have heads full of humidity and phlegm—they are destitute alike of strength and activity[m]."

Southerly climate.

These observations refer to the southern coasts of Greece and of Asia Minor, in the neighbourhood of the island where Hippocrates was born. According to Mariti, the whole of the south coast of the island of Cyprus frequently experiences an unwholesome state of the atmosphere; brackish waters are in abundance there, and the country is very unhealthy. The same observations hold true as to the coasts of Caramania, or ancient Cilicia. At Satalia, at Agas, and at Adana, the bad air compels the inhabitants, during summer, to retire towards the mountains. And

[l] Σκοπειν και βασανιζειν; literally, to look for and bring to the test.

[m] Hippocrates, de Aer., aquis, locis, §§ 9—14, edit. de Coray.

why is the southern exposure of these countries so unwholesome? Strabo and Quintus Curtius tell us the reason. "Because Cilicia is a narrow plain, bounded on the north by the chain of Mount Taurus; and the winds which flow from the south being reflected by the mountains, cause suffocating heat; besides, there are marshes and stagnant ponds on the coast[n]." On the other hand, Cicero informs us, that the snow rendered the passage of Mount Taurus difficult before the month of June[o].

This is the reason why the temperature of the air and of the waters of Cilicia experience variations too great not to be hurtful. This observation undoubtedly admits of being applied to other countries where the same combination of circumstances takes place; the southern wind is known to be generally damp, hot, and unwholesome, upon the shores of the Mediterranean. In the island of Lesbos, according to Vitruvius, southern winds often cause epidemic complaints: in Attica, they once occasioned the plague. Virgil describes them as winds "whose damp breath is injurious to orchards, corn, and flocks[p]."

Let us extend this general character to the coasts of the Gulph of Persia. The southern winds there bring on the rainy season, and suffocating heat. At Susa, says Strabo, the inhabitants dare not expose themselves to the heat of the sun in the middle of the day. At Bassora, according to Otter, the southern wind paralyzes all the strength of the human body.

But let us pass to the opposite coast of Africa. Aristotle, in his day, knew that the southern winds are often cold, and always dry there, because they blow from Mount Atlas[q]. At Paris too, we have southern winds charged with the atmospheric cold of the mountains of Auvergne. Contrary examples.

[n] Strab. Georg. XIV. 260. Casaub. Atreb. Quint. Curt. III. c. 9—11.

[o] Cicer. Epist. ad Famil. XV. 4.

[p] Virg. Georg. I. 443. Bucol. II. 57. Vitruv. i. cap. 6.

[q] Aristot. Problemat. xxvi. 16—51. Comp. Aulus Gellius, xvi. 11. Lucan, Pharsal. ix. 447, *sqq.*

These same winds are very cold in Suabia and in Bavaria, for they pass over the Alps. Everywhere winds are modified according to the nature of the places over which they blow.

We do not, however, stand in need of these examples. Does not Hippocrates himself immediately add, "But even amongst those towns, (exposed to the hot southern winds) such as are very much open to the sun and to the winds, ought to experience these disagreeable alternations in a less degree. In fact, Tarsus in Cilicia, notwithstanding its southern exposure, furnished an example of wholesome climate, and limpid waters[r].

Northern climate.

The Northern climate of Hippocrates is not more universal than that which we have been considering. Winds from the north at Archangel, and at Dantzic, bring humidity, and are less cold than the southern winds[s].

These variations in the nature of winds do away with the other consequences. A proof of this is to be found in the Spanish peninsula, under the same latitude as northern Greece. The Asturias are exposed to the north; the climate is cold, but extremely damp. The prevalent diseases are a species of leprosy, dysenteries, scrofulous swellings, and others of that kind which the father of medicine attributes to southern exposures.

Eastern climate.

The resemblance which Hippocrates endeavours to establish between the southern and eastern climate, is also unfounded as to western Europe, where the south winds more generally resemble those from the west in humidity and mildness; whilst, on the contrary, the winds from the east are evidently colder even than those from the north, because these east winds come to us over central Russia, the Uralian mountains, and the confines of Siberia. The catarrhal affection which was prevalent in 1782, was gene-

[r] Dio Chrysostom, Orat. de Tarso.

[s] Kant, Geographie Physique, iii. Part ii. p. 110.

[t] Casali, Annales des Voyages, t. viii. p. 76, *sqq.* Thierry, Observ. Medicales sur l'Espagne.

rally ascribed to the severe cold suddenly brought on by an eastern wind.

We are equally unwilling to admit the theory of Hippocrates with respect to *western climates.* "Every nation," says he, "exposed to the *western winds*, has an unwholesome climate, the waters which they drink are not limpid, because the morning fogs mingle with them before the sun has had time to dispel them. Secondly, The inhabitants of these places are exposed to sudden changes of temperature; for, in the summer mornings, cool winds blow, and dews fall. In the afternoon, the heat torments them; they have a pale complexion, and a feeble constitution. Breathing always a thick and unwholesome air, their voice becomes rough and hoarse. The west presents to us the image of autumn; the people who live under this climatological constitution, should participate in the maladies of the inhabitants of the north and south." A commentator adds, "They will join the ferocity of the natives of the north, to the fickleness of those of the south." Western climate.

All these observations of Hippocrates, though sound and just, when properly restricted, become puerile and absurd when they are extended into general rules.

Who are there that lie more to the west than the Portuguese? Have they therefore a raw and hoarse voice? On the contrary, their language is infinitely softer than that of the Spaniards. Is the air which is breathed in Portugal thick and unwholesome? So far from it, that the English send thither their invalids to recover their health. Look to the Irish, who are continually exposed to storms from the west; have they a pale complexion? On the contrary, a native of Ireland may be distinguished by the freshness of his looks. Objections.

Has Hippocrates then advanced assertions which are utterly false? We disclaim the thought of bringing forward such an accusation. But he meant to speak only of certain countries of Greece, and his observations are just and profound when they are thus locally interpreted. Local examples.

All the western coasts of Illyria, of Epirus, and of the

Peloponnesus, have in fact that inconstant climate which Hippocrates compares to autumn. There the west wind often brings rain and fogs; and even in our days the impetuous and baneful west wind, of which Homer so often sings, is still felt in these regions [u].

The Elians, according to Strabo, Hesychius, and Eustathius, had, of all the Greeks, the rudest pronunciation; that nation and their colonies often inserted a canine letter (r) where the other Greeks put none, they said *heror* or *her* instead of *Heros* [x].

The Etolians probably spoke still worse, their ferocity besides is well known. Polybius and Thucydides consider them as *semi-barbarians* [y]. Lastly, the inhabitants of the island of Zante, according to Scrofani, have a pale complexion. The western Greeks were in general not so tall as those of the east and the north. Ulysses was called by the Etrurians the *wandering dwarf*.

Principles of classification of climates.

Thus are the observations of Hippocrates justified; and this, we presume, is the true way of reading and explaining an ancient author, by comparing him with other writers who were his cotemporaries, or his countrymen. The critical examination of the four climates of Hippocrates should convince us of the impossibility of founding a classification of temperatures on the principle of the *causes* which produce them, since every one of these causes varies with geographical circumstances. It is by considering the principal combinations of the properties which characterise climates, that we can classify them in a general manner. Heat and cold may be accompanied with humidity and dryness; from thence there results four principal climates.

Hot and dry climate.

We have first the *hot and dry* climate. Such is in an extreme degree that of the deserts of Sahara and of Arabia. The earth beneath is scorching, the sky above is on fire; even the brackish water is scarce and valuable as gold; plants languish for want of nutriment; the men and

[u] Homère, Odyss. v. 295.; xii. 289.; xiv. 458.

[x] Strab. x. 308. Hesychius, in voce, Eretria. Eustat. in Illiad. ii. 279.

[y] Polybius, xvii. p. 476, édit. Casaub. Thucydides, iii. chap. 94.

animals indeed are strong and brawny, but few in number; olive complexions and bilious temperaments prevail amongst the natives of these countries. Their ferocious and sanguinary dispositions correspond to the character under which nature has appeared in these dreary and inhospitable regions.

Hot and humid climate.

The *hot and humid climate* prevails in Bengal, in Mesopotamia, in the coasts of Zanguebar, Senegambia, Guayana, and Panama; these countries enjoy the verdure of perpetual spring; and furnish the most gigantic productions of the vegetable kingdom; but there also reptiles of unwieldy length wallow in the mud of marshes, steaming with pestilence; there man, robust in his frame of body, propagates with rapidity, but his moral character is sunk almost as low as that of the brutes. The deep swarthy skin, and the phelgmatic temperament belong peculiarly to these countries. The *cold and dry* climate supports a hardy, though certainly not a profuse vegetation; the waters are generally pure but hard; animals and men, respiring more oxygen, are strong, active, and healthy; the moral and the physical part are in a state of equilibrium. They propagate slowly but with regularity; the sanguine temperament, and the white skin, are characteristic of this climate, which comprehends the greatest part of Europe and of Asia.

Cold and dry climate.

Cold and humid climate.

The *cold and humid* climate, in its extreme, such as is experienced in Siberia, and to the north of Canada, envelops the atmosphere with unwholesome fogs, and reduces vegetation to a few cheerless stunted shrubs, and to creeping moss. The animals are covered with a thick fur, under which they remain torpid one-half of the year. Man himself, tall, but weak and sluggish, thinks only of defending his physical existence against the unkindness of nature. The red copper-coloured skin, and the melancholic temperament, seem to be the native growth of such a climate. By unfolding, in this manner, the views of the celebrated philosopher Kant[z], our design has been only to exhibit a

[z] Memoir upon the four principal constitutions of the human race, in the collection, entided, Mundane Philosopher by Engel. (in German.)

sketch of the combinations of extreme temperatures, and their most probable effects. We admit, that the four principal climates are, perhaps, no where to be found without some modifications, which alter their nature. These *modifications* are of two kinds; the one kind arises from a succession of two different climates in the same region; the other is owing to the more or less elevated degree of any of the four qualities which constitute climate. It is these modifications which, in opposition to the system of Hippocrates, can entitle any climate whatever to the appellation of *temperate*, since the true sense of this term denotes an atmospherical constitution in which the hot, the dry, and the humid, are equally moderated by each other. Thus, in Egypt, the succession of humid heat, during an inundation, and of dry heat for the remainder of the year, tempers a climate, which, without either alternative, would be insupportable. Thus, the Dutch see with pleasure the dry cold succeed the humid cold, which, of itself, would render their country extremely insalubrious. At other times, the succession taking place too rapidly, or the two temperatures being too remote the one from the other, the climate is rendered more disagreeable than if one uniform temperature continued. It is thus that the inhabitants of Astrachan, and of some other towns, feel in summer the heat of Africa, and in winter the cold of Siberia. These atmospherical constitutions are also modified by the solar climate; thus, the dry heat, which renders Sahara almost inaccessible, becomes, at Madrid or at Marseilles, a temperature very suitable to man. The baneful effects of humid heat, are, in like manner weakened, as we recede from the equator. On the other hand, we find the cold, dry or damp, more and more supportable as we advance from the pole towards the tropics. For example, at Bergen in Norway, and at Brest in France, there is always the same constitution of winter rendered variable and humid from the vicinity of an ocean which never freezes. But how great is the difference in the intensity of the cold!

Modifications of these climates.

These observations upon the true acceptation of the word

climate naturally lead us to take a general view of the different temperatures of the five zones into which we are accustomed to divide the globe.

The *torrid zone* experiences only two seasons, the one *dry*, and the other *rainy*[a]. The former is looked upon as the summer, the latter as the winter of these climates; but they are in direct opposition to the celestial winter and summer,—for the rain always accompanies the sun, so that, when that luminary is in the northern signs, the countries to the north of the line have their rainy season. It appears that the presence of the sun in the zenith of a country, continually heats and rarefies its atmosphere. The equilibrium is every moment subverted, the cold air of countries nearer the poles is incessantly attracted, it condenses the vapours suspended in the atmosphere, and thus occasions almost continual rains. The countries of the torrid zone where no vapours rise into the air, are never visited by the rainy season. Temperature of the torrid zone.

Local circumstances, particularly high chains of mountains, which either arrest or alter the course of the monsoons and the winds, exercise such influence over the physical seasons of the torrid zone, that frequently an interval of not more than several leagues separates summer from winter. In other places, there are two rainy and two dry seasons, which are distinguished by the names of *great* and *little*.

The heat is almost always the same within 10 or 15 degrees of the equinoctial line; but towards the tropics, we feel a difference between the temperature which prevails at the moment the sun is in the zenith, and that which obtains, when, in the opposite solstice, the solar rays falling under an angle of more than 47 degrees. We may therefore, with Polybius, divide the torrid zone into three others. The *equatorial zone*, properly so called, is temperate, compared with the *zone of the Tropic of Cancer*, composed of Difference of the equatorial and tropical regions.

[a] Varen. Géographie Générale, ch. xxxvi. propos. 10. *sqq.* Bergmann, Geog. Physique, § 143.

the hottest and least habitable regions of the earth. The greatest natural heat ever observed, which is 35 degrees of Reaumur, (111° Fahr.) has been at Bagdad, at 33 degrees of latitude. The *zone of the Tropic of Capricorn* contains but little land, but it appears to experience momentary heats of extreme intensity.

Most of the ancients, disregarding the observation of Polybius, conceived that the heat continued to increase from the tropic towards the equator. Hence they concluded that the middle of the zone was uninhabitable. It is now ascertained that many circumstances combine to establish even there a temperature that is supportable. The clouds; the great rains; the nights naturally very cool, their duration being equal to that of the days; a strong evaporation; the vast expanse of the sea; the proximity of very high mountains, covered with perpetual snow; the trade winds, and the periodical inundations, equally contribute to diminish the heat. This is the reason why, in the torrid zone, we meet with all kinds of climates. The plains are burnt up by the heat of the sun. All the eastern coasts of the great continents, fanned by the trade winds, enjoy a mild temperature. The elevated districts are even cold; the valley of Quito is always green; and perhaps the interior of Africa contains more than one region which nature has gifted with the same privilege.

Nothing equals the majestic beauty of the summer in the torrid zone. The sun rises vertically—it traverses in an instant the burning clouds of the east, and fills the heavens with a light, whose effulgent splendour is unobscured by a single shade. The moon shines here with a more brilliant lustre, Venus blazes with purer and more vivid rays, and the milky way glitters with augmented brightness To this magnificence of the heavens, we must add, the serenity of the air, the smoothness of the waves, the luxuriance of vegetation, the gigantic forms of plants and animals, all nature more grand, more animated, and yet less inconstant and less changeable.

The temperate zones, on the other hand [b], are indemnified by the mild and varied charms of spring and autumn, by the moderate heat of summer, and the salutary rigours of winter. This succession of four seasons is not known beyond the tropic, nor towards the poles. Even that part of the northern temperate zone which lies between the tropic and the 35th degree of latitude, in many places resembles the torrid zone. Until we come towards the 40th degree, the frost in the plains is neither intense nor of long duration—it is equally unusual to see snow fall there, though unquestionably it is not true, that when a fall of snow does take place, the ladies of Rome or of Naples leave the theatre to enjoy so extraordinary a spectacle, or that the Academicians run out, with their glasses in their hands, to examine this singular phenomenon. Elevated countries feel all the rigour of winter—and the trees even in the plains lose their foliage, and remain stripped of verdure during the months of November and December. Seasons of the temperate zone.

It is from the 40th to the 60th degree, that the succession of the four seasons is most regular and most perceptible, without however endangering the health of man: And it is within these latitudes that we must look for the nations that are most distinguished for knowledge and civilization, and those who display the greatest courage by sea and by land. It would appear, that in countries where there is no summer, the inhabitants are destitute of genius, or at least of intelligence and taste; while in those regions where there is no winter, true valour, constancy, and loyalty, as well as other civil and military virtues, are almost unknown. But, let us remember, that it is man himself, who has in a great measure created these salubrious climates;—France, Germany, and England, not more than twenty ages ago, resembled Canada, and Chinese Tartary, countries situated, as well as our Europe, at a mean distance between the equator and the pole. The most temperate climates.

[b] Bergmann, Geographie Physique, § 114

Seasons of the frozen zone.

Beyond the 60th degree, and as far as the 78th, (which appears to be the limit of the habitable earth in the northern hemisphere,) only two seasons are generally known; a long and rigorous winter, succeeded often suddenly by insupportable heats. The power of the solar beams, though feeble, from the obliquity of their direction, accumulates during the days, which are extremely long, and produces effects which might be expected only in the torrid zone. There have been examples of forests having been set on fire, and of the pitch melting on the sides of ships. In winter, on the contrary, brandy has been frozen in heated rooms; a crust of ice has covered even the sheets of the bed; the earth has been found frozen to the depth of 100 feet[c]; and mercury, congealed in the thermometer, leaves the degree of cold indeterminate. I speak here of extreme cases, and of the zone in general. For, in some places, a southern exposure, and the neighbourhood of the ocean, soften the climate to an almost incredible degree. Bergen, in Norway, and the whole of the adjoining coast, between 60 and 62 degrees of latitude, has a very rainy winter, but seldom snow or frost—that season of the year is there less rigorous, and requires less fuel than at *Cracovia*, or *Prague*, or *Vienna*, in *Austria*, between the 48th and 50th degrees of latitude. The frigid zone enjoys an atmospheric calm which is unknown in temperate regions—it has no storms, no hail, scarcely a tempest—the splendors of the aurora borealis, reflected by the snow, dispels the darkness of the polar night. The days for several months, though of a monotonous magnificence, astonishingly accelerate the growth of vegetation. In three days, or rather three times twenty-four hours, the snow is melted, and the flowers begin to blow.

The greatest cold of the southern atmosphere.

This succession of physical zones is not equal in the two hemispheres. When speaking of the ice of the sea, we observed, that, in the arctic seas, we scarcely meet with the large floating masses before we arrive at the 70th degree, nor the stationary fields, until towards the 75th or 80th de-

[c] Gmelin, Voyage en Sibériæ.

grees of latitude; while, in the antarctic seas, both occur at from 50 to 60 degrees of southern latitude. In the island of Terra del Fuego, in that of Sandwich, and in several others situated towards the 54th and 59th degrees of south latitude, the mountains even in the southern summer remain covered with snow quite to the shores of the sea [d].

This diminution of heat appears to cease all at once between the 30th and 40th degrees of latitude; for hot winds arise from the interior of New Holland, whilst the mountains of Van Diemen's Land remain covered with perpetual snow [e]; thus there is felt in these latitudes the most sudden transition from a suffocating heat to a very sensible cold [f].

Astronomers [g] seem to ascribe this contrast solely to the shorter stay which the sun makes in the southern signs; that is to say, to the greater rapidity of the earth's motion when it is in its perihelium. The sun's stay is 7 days and 18 hours shorter in the meridional than in the northern signs. But the difference produced by this cause would be only $\frac{1}{23}$, while the actual existing difference is nearly $\frac{1}{7}$. The theory of radiant heat has furnished another explanation; and an attempt has been made to demonstrate, that in a given time, the southern hemisphere gives out a greater quantity of its own constant heat than the northern [h]. But this cause should not all at once cease to act towards the 40th degree. It is necessary, therefore, to search upon for the cause of this phenomenon in the earth itself. Different opinions.

The vast extent of the antarctic seas, the total absence of any great extent of land, and the form of the continents which terminate towards the south, almost in points, open a free and unincumbered field to the currents from the polar seas; and allow them to push forward the icy masses in Causes of this phenomenon.

[d] Foster, Cook, Dalrymple, &c.

[e] Péron, Voyage aux Terres Australes, ii. (in edit.)

[f] Labillardiere, Voyage à la recherche de Pa Pérouse, ii. 27.

[g] Mairan, Mém. de l'Académie, 1765, p. 174. Æpinus, Cogitat. de Distribut. calor. per tellurem.

[h] Prevost, sur le calorique rayonnant, p. 328, *sqq.*

every direction from the south pole towards the southern temperate zone. There some of them accumulate, and are stopped by getting entangled with each other; some of them are hindered from advancing further by the force of the general movement of the ocean towards the west, which must now be very perceptible; and some of them melt by the action of the solar heat, which must be considerable at 50 degrees, although it has but little effect upon the thermometer, because the ice in melting absorbs it the moment it is diffused through the air.

As there is no *fixed limit* where the motion of the polar waters towards the equator stops, and changes into the general motion towards the west[1], this change depending on the influence of several local and temporary causes, as little will there be any determinate boundary for the southern ice. Accordingly, navigators have sometimes met with entire and fixed islands of ice towards the 50th degree, and sometimes they have advanced 10 degrees nearer the southern pole, and met only with floating pieces. These variations of their latitude, under the same meridian, seem to establish our explanation: it seems, indeed, impossible to assign any other sufficient cause than the action of the polar currents. These moveable masses of ice, propelled on all sides towards the tropic of Capricorn, are stopped in their progress only when they meet with currents which set to the west, and which, as they draw them along, impart to them a compound motion—a motion which, being constantly modified by the equatorial current, makes them describe a spiral line until they melt. They thus enter unexpectedly into a zone otherwise temperate, where their presence causes these sudden transitions from heat to cold, and those extensive fogs, which are spoken of by navigators.

Quantity of southern polar ice.

In adopting this explanation, we are under no necessity of supposing the *quantity* of southern ice to be so enormous as it would be according to any other hypothesis; for upon our principle, this ice, which appears towards the

[1] See Book xiv. p. 335 337, *et seq.*

50th and 60th degrees of latitude, would form but a very small part as to quantity when compared with a single mass of fixed ice around the pole, indeed they would consist of only a girdle or belt of variable thickness, behind which there might be found vast expanses of sea, which from time to time would contain no ice.

Whether the general temperature of the globe changes.

The theory of physical climate suggests still another inquiry: Can we admit a change in the direction of the terrestrial axis? This inquiry is highly interesting, not only to geographers, but to the whole of the human race. Without the obliquity of the ecliptic, without that angle of inclination, which exists between the plane of its diurnal solution and the plane of its orbit, there would be no inequality between the days of winter and summer, and no change of seasons as far as that depends upon celestial causes; the equator would be still more constantly heated than it is at present, and we should perceive the heat diminish on both of its sides in a very rapid progression; each climate would have an invariable temperature, which would be that of its present spring and autumn, but very probably somewhat lower. The earth would then be scarcely habitable beyond the 45th or 50th degree of latitude. Here, then, would be that eternal spring which the poets wish us to deplore the want of. Many philosophers and astronomers entertain the opinion that the ecliptic and the equator actually tend to coincide. The ancient astronomers found the obliquity of the ecliptic to be 24 degrees. Eratosthenes, 250 years before Christ, found it to be 23 degrees 50 minutes. Albategnius, in 880, 23 degrees, 35 minutes, 40 seconds. Tycho-Brahe, in 1587, 23 degrees, 31 minutes, 30 seconds. It oscillates in our day about 23 degrees, 23 minutes. Its average diminution for each century seems to have been hitherto 57 seconds. But Euler and Laplace have proved, by profound calculations, that this diminution arises from the mutual attraction of all the planets, the orbits of which being differently inclined, seek constantly to mingle in the same plane, from whence there result only temporary inequali-

ties, confined within determinate bounds. The sun contributes above all constantly to bring back all these variations to the point whence they had originated. Were it not for the attractive force of the sun, the planets, especially Jupiter and Venus, might have power to change the obliquity of the ecliptic from 10 to 12 degrees. But the mighty monarch of the planetary system represses these attempts, and prevents the obliquity from ever varying more than from 2 to 3 degrees. In general the whole system of the world appears now to oscillate round a mean state, from which it deviates only very insensibly either to the one side or the other. The violent contests between the great powers of nature have ceased; we live in a period of physical repose, but we perceive around us the traces of anterior revolutions. These are about to become the subject of our inquiries.

BOOK XVIII.

Continuation of the Theory of Geography. Of the Revolutions which have taken place upon the Surface of the Globe.

We have described the existing physical state of the terrestrial globe, at every stage in our progress. It would seem that the order of things which now subsists, must have been preceded by several orders of a different kind. The existence of the material world is only a series of metamorphoses. As in the ocean wave sinks into and blends with wave, so the elements, agitated by a never-ceasing motion, mingle, and combine, and replace each other, under forms continually changing and continually renewed. General views.

In this ebb and flow of existence and destruction, we float along like the light and unsteady leaves, which are borne, heaved aloft, hurried on, and swallowed up by one and the same billow. How then should we hope to form a conception of the unmeasured chain of revolutions which our globe may have undergone? We walk upon the wrecks of anterior worlds; but can we compute their number? The lapse of ages has heaped up ruins upon ruins: at every step we tread on monuments, upon which the hand of nature has engraved the history of the globe; but the record is couched in hieroglyphical symbols, the key to which shall never perhaps be found.

The feeble light which reasoning or experience has furnished, relate to two classes of changes which have taken place on the globe. Some repeatedly occur under our own observation, or at least have been observed by men who have conveyed accounts of them to us. Other revolutions Two classes of terrestrial revolutions.

are known to us only by their astonishing effects, and by traces which it becomes us to follow in silence, resolved to stop where they cease to guide us. It is of importance to separate, with rigorous exactness, the class of *supposed* or *inferred* facts, from that of *established* facts. But enthusiasm has already singularly perplexed this question: the inventors of geological systems have brought forward as historical facts, events which have not any contemporary and substantial authority: the vague descriptions of poets, and even popular traditions, have been collected and repeated without undergoing any scrutiny. Aristotle complained in Greece of this abuse. Pliny, in a later age, introduced it at Rome. As to the moderns, who have undertaken to write the history of the changes which have happened on the surface of the globe, they have chosen rather to display superficial erudition, by compiling anew what the ancients had compiled before them, than to make use of that difficult art by which facts of an established and definite character are distinguished from uncertain traditions that are altogether unfit for the purpose of the philosopher. It is an undertaking beyond our strength to re-establish historical truth in all its purity: we shall, however, refrain from repeating any of the fables with which geologists have adorned the first ages of the history of the globe.

Confusion of supposed and established facts.

The changes whose actual occurrence is capable of proof, are marked by characters which are extremely different. Some have taken place with the most inconceivable rapidity; while, in the imperceptible progress of others, we perceive that the power of time has no limits.

Causes which change the surface of the earth.

Of all the known powers and agents, there is none which has not contributed, however little it may have been, to change the surface of the globe. Fire performs the most conspicuous and noisy part; but water appears to have had a still wider sphere of activity. The air conceals under its appearance of weakness a very powerful disintegrating and recompounding energy. The earth itself, by yielding obedience to the laws of equilibrium, has assisted in giving shape to its own surface. And the labours of

man, though in the last rank, occupy a place in some corners of this vast picture.—We shall now take a rapid survey of the annals of the globe.

Decomposition by air and meteors.

The atmosphere generates meteors whose slow but continual effects, by accumulating from age to age, must collectively amount to an incalculable sum.

The winds, which uproot entire forests, have laid, in some remote period, the foundations of coal mines. The rains, by running down the sides of the mountains, bare and roughen some parts of them; whilst, to other parts, they give roundness and elevation. The hail and the snow harden and accumulate into vast masses of ice and snow, whence flow the impetuous rivers which excavate the valleys. Ramond observed the summits of the Pyrenees everywhere furrowed by the thunderbolts. But the air of itself is possessed of a very considerable dissolving power; it ultimately decomposes all known substances. The most solid rock is cleft, and divided into stones; the stones crumble into gravel, or dissolve into sand, which are lifted by the winds, or rolled by the waters to a great distance from their original soil.

The succession of heat and humidity accelerates that slow disintegration which is continually going on before our eyes. The air disseminates the pollen, or fructifying dust of plants, transports whole clouds of sand and of volcanic ashes, and holds in solution a great number of watery, saline, and earthy particles. It contributes, therefore, incontestably to change the surface of the earth.

Extension of moving sands.

This action of the air is especially perceptible in the continual extension of *moving sands*. The effects of it have been severely experienced near St. Pol de Leon, in Bretagne, where a whole village was so completely buried beneath the sand, that nothing was seen but the spire of the church[a]. England, Jutland, and Scania, have undergone, and do still undergo, similar inundations. In Greenland, the famous ridge of hills of pure ice, named the Iceblink, is situated between two promontories of moving sand with

[a] Mémoires de l'Academie des Sciences de Paris, 1722.

which the winds sometimes strew the decks of vessels more than 12 leagues distant [b]. Thus the phenomena of the African deserts are met with near the pole. In Jutland, we have seen places where the sand is so extremely fine, as to exhibit the appearance of a fluid mass in which we might swim. It is easy to conceive that the wind may carry this powder to considerable distances, and in this manner create new deserts of sand.

Labours of man.

The industry of man, by paving streets, by building houses, by spreading manure over the fields, by erecting dikes along the sides of rivers, tends insensibly, but powerfully, to elevate the soil of a country. We perceive this chiefly in towns near ancient buildings. To enter the Pantheon at Rome, it was once necessary to ascend eight steps: we must now descend as many. Nor should it be alleged that the building has sunk, for it has preserved the same level for two centuries past [c].

Changes arising from vegetables.

The aquatic plants often change a marsh into a damp meadow. These are, first, the *hippuris*, the *utricularia*, the *equisetum*, and different rushes which form with their interwoven roots a floating tissue upon the muddy water. Next, the *sphagnum palustre* is diffused over the whole surface, absorbs the water like a sponge, and creates a bed for the briars and lichens which thicken and raise the soil by their annual depositions. At other times, the expanse of a tranquil bay is peopled by *water lilies*, the *arundo phragmites*, and other plants which retain the earthy particles cast up by the waters without. As soon as this mud has acquired a little solidity, we see the willows spring up, together with osiers and other trees which prefer an aquatic soil [d].

Vegetation contributes also still in various ways to change the appearance of the earth. Observe that slender plant, that moss which mounts up along the walls of a deserted

[b] Crantz, Relation du Groenland. Egede, &c. &c.
[c] Bergmann, Géographie-Physique, § 148, ii. 170.
[d] Misson, Voyage d'Italie, ii. 195.

palace. By being repeatedly decomposed and renovated, it will, some ages hence, have covered, and even have buried beneath it, those stately piles which were reared by luxury for the residence of sovereign power. The remains of the vilest animals are collected in heaps where the thrones of monarchs once glittered with splendour. Brambles cover the temple of Olympic Jupiter, and the towers of Babylon lie concealed beneath the grass.

Sinking down and revolutions of mountains.

Mountains *sink down*, or *separate into fragments*, from the agency of other causes than earthquakes or volcanic explosions. Sometimes the waters of a rapid river, of an agitated lake, or even of a subterraneous current, waste, consume, and secretly undermine a mass of rocks, or of solid earth. The beds of sand, gravel, clay, and chalk, which serve as a support, are dissolved or swept away; an excavation is formed, and the superincumbent mass sinks down by its own weight. At other times, subterraneous waters penetrate under a new stratum, under a vegetable bed; they at first support this crust, then loosen it, tear it off, and at last finally wash it away piece-meal, or swallow it entirely up. Sometimes there is a fissure, by means of which part of a mountain is detached from the principal mass, and overturned in consequence of being deprived of its natural support. These kinds of fissures are in the argillaceous rocks, the effects merely of dryness, accompanied by the shrinking in of certain particles; in calcareous rocks, a species of fermentation may very much contribute to produce them; and in granite rocks they appear to arise from the decomposition of certain laminæ of a less powerful crystallization, acted on by the oxygen of the atmosphere. The granite of Finland, named Rapahiwi, is decomposed wherever there predominates in its composition ferruginous, or a kind of sulphuro-ferruginous mica[c]. Bergmann has often seen the petrosilex covered with a slightly coherent crust, which, when washed off by the waters, exposes to view small fragments of quartz and ferru-

[c] Gadd, Dissertations sur le Granite, cité par Bergmann, Geog. Phys. § 151.

ginous garnets. Thus the mountains may be destroyed even by the influence of that imperceptible humidity which is inherent in all terrestrial substances.

General sinking of the globe.

There can be no doubt that these two kinds of subsiding, must have contributed to the formation of the existing surface of the globe. We perceive everywhere around us nothing but wrecks and ruins; those beds of rocks, displaced, overturned, shattered; those lakes so deeply excavated; those caverns which reach down towards the centre of the earth; those peaks which tower to the sky; those precipitous coasts which surround as with an immense rampart all the seas of the globe; those alps which overhang Italy; those Andes which plunge their gigantic sides into the ocean; those forests, those races of quadrupeds, those aquatic animals buried in the earth in mingled confusion; all these circumstances impress us with the awful and overwhelming thought, how vast must have been the heavings and agitations which have contributed to give to the globe its present appearance.

M. Deluc has very happily applied this physical truth to illustrate the account of a universal deluge contained in the sacred writings. According to him, this catastrophe, which some have endeavoured to represent as impossible, may be naturally explained, merely on the supposition of a general sinking down of the inhabited regions of the earth; then the waters of the sea, instead of being elevated, as has been generally imagined, would have needed only to follow the laws of gravitation, in order to cover the *antediluvian* world, and leave dry our present continent.

But we wish to speak here of facts of which history has preserved the details.

Subsidings through excavations.

The subsidings which take place from excavations made by water, happen yearly in mountainous countries along rivers. It is thus that the Rhone has formed the vault under which it appears to lose itself; it is thus that the Adige swallowed up the town of Neumark and others in 1767. In the south of Norway, the rapid Glommen descends from the summit of the Dofrine mountains towards the North

Sea, and forms, a little above its mouth, the fine cascade of Sarpen. The eddy of the waters of the cascade have formed under the bank a subterranean lake 600 feet in depth. On the 5th February 1702, the Castle of Borge, with all its dependencies, was engulphed in this excavation, and entirely disappeared, so that there appeared nothing in its place but a lake 800 feet long, and from 300 to 400 broad [f]. The disaster which befel the town of Pleurs, in the country of Chiavenna, arose from a similar cause.

Rivulets and springs without number wore away the frail foundations of Mount Conto; on the 25th August 1618, the masses of rock of which that mountain was composed, separated from each other and rolled upon the town, which they completely overwhelmed, as well as the small town of Schilano; 2430 individuals perished; a lake occupied the place where 200 elegant houses once stood. All the wealth, which for a century commerce had amassed, was at once restored to the maternal bosom of the earth [g].

The plains experience depressions of another kind. The platforms of turf suspended upon water, sink under the weight of forests, houses, and inhabitants. Ireland every year sees the number of its lakes increase by the sinking in of its bogs. It is to these that *subterrancous forests*, in some measure, owe their origin. There are some which, like those on the shores of Lincolnshire [h], are formed conjointly by the sinking down of marshy coasts, and by ancient invasions of the sea. Others, like those which have been discovered near Morlaix [i], appear to owe their subterraneous situation to changes anterior to the existing state of the globe, but for the most part, they are met with in turf or peat grounds. In the Isle of Man, accordingly, in the midst of a marsh, at the depth of 20 feet, fir trees are found still on their roots. At Halfield-chace, we find trees

Origin of subterranеous forests.

[f] Pontoppidan, Hist. Nat. de la Norwège, i. ch. 3. § 14.

[g] Camerari, Dissertat. vi.

[h] Corréa de Serra, dans les Annales des Voyages, i. 169. *sqq.* Truglaye, No. 110. du Journal des Mines.

which have their nuts and acorns lying at their sides. Holland, Switzerland, and France, present similar facts; but it is Sweden which furnishes us with the most curious example. Near Asarp, in West Gothland, there are two peat bogs composed of a thick mud, and of a slight turf. We discover there a great quantity of trunks, and roots, which are carried off every year to serve as fuel; the following year they are equally abundant, which arises unquestionably from an immense collection of trees buried in this great ground, and raised to the surface by the annual thaw [k].

Lakes formed by subsidings.

In the Electoral Marche of Brandenburg, there is the lake of Arendt, formed by two subsidings, the one, it is believed, happened in 815, the other in 1685. How many lakes are thus formed in Prussia and in Poland! How many other events are there of this nature, the knowledge of which is lost to us, or has been disfigured by tradition! Strabo tells us, that around the Lake Copaïs, in Bœotia, the sinkings of the ground were very numerous, and often changed the course of the river Cephissus, which at last flowed in subterraneous canals constructed by the hand of man. As these canals are no longer kept in repair, and as the lake Copaïs is changed into a marsh, we may ask, what is become of the waters of the Cephissus? It appears only too probable that they have hollowed out a subterraneous reservoir, an invisible lake, but which may one day swallow up Bœotia, and thus renew the *deluge of Ogyges*.

We have spoken of subterraneous lakes, and amongst others of that in the West Friezland, which was discovered in the 12th century; by degrees there was formed on its surface a crust of peaty and slimy substances, which in their turn were covered with vegetable mould. This crust is now strong enough for a carriage to pass over it, and to be laboured, sown, and reaped. At the same time the inhabitants have only to make two or three holes, four

[k] Bergmann, Géographie-Physique, ii. 244. Rothof, Mém. de l'Academie des Sciences de Stockholm, 1767.

feet deep, to find water to serve them for steeping their flax. There probably exists a subterraneous lake near Narbonne, in the territory of Liviere. We there see five abysses, named the *Ocliols*, of an extraordinary depth, and filled with fish; the earth which surrounds them tumbles under the steps of the adventurous peasants who are attracted thither for the sake of fishing.

Ground suspended over lakes.

We may easily conceive the disasters which, from time to time, indicate the existence of these subterraneous lakes, in places where no one suspects them. In 1792 a lake was formed in the town of Lons-le-Saulnier; several houses disappeared, as well as a part of the high road from Lyons to Strasbourg[1]. It is supposed that this was an old pond of brackish water; on which at first there was formed a pellicle, then a slight vegetable crust, and then ground, to all appearance, solid; but a great drought having made the subterraneous waters fall, this crust was deprived of support, and consequently sunk down. Mount Jura presents a number of vestiges of similar sinkings. The Pyrenees, another calcareous chain, exhibit them in as great abundance. Buffon relates, that a mountain in 1678, having sunk down into subterraneous cavities filled with water, caused a great inundation in a part of Gascony. The Julian Alps, where the famous lake of Cirknitz is, contain in their numerous caverns many similar reservoirs.

Justly, then, might Seneca ask, "In what part of the globe has not nature waters at her command, to assail us with, whenever she pleases? Our excavations, our pits, almost every where terminate in water. Let us add, also, those immense invisible lakes, those subterraneous seas, those rivers which are enveloped in continual night. How many causes are there of inundation in those waters which flow beneath us and around us? For a long time prisoners, they will one day set themselves at liberty; the rocks, open on all sides, will furnish numerous currents of water,

[1] Bertrand, Nouv. Principes de Géologie, p. 198.

which will rush towards the ocean. These deluges of water or fire happen whenever it pleases the Almighty to recommence a more perfect order of things."

We are now to speak of subsidings, in which the agency of water has not been immediate and predominant; for rarely does a disaster happen, in the production of which this element is entirely inactive.

Mountains without cohesion.

Many mountains, as we have seen, are originally composed of large stones, perfectly detached from each other. There are many such mountains between Norway and Sweden. A transverse section of Mount Quedlie shews a mass or stratum of 240 feet, composed of small flat stones—some calcareous, some sandy, and always without any cement to bind them together. The slightest force is sufficient to roll down these masses, which have been formed by changes anterior to the records of history.

Effects of cold.

There are other causes which concur in decomposing the most solid mountains; extreme cold often makes large blocks of rock burst asunder and tumble down. In West Gothland, near Hunneberg, there are two regular pillars detached from a rock, solely by the action of frost[m].

Norway suffers great devastations from the avalanche of stones, which are in like manner occasioned by the effects of cold. In the milder climates, the successive action of cold and heat is not less destructive, though more silent. In these same mountains of West Gothland, of which we have just now spoken, Bergmann has observed that the rocks of trapp had a paler and more porous crust on the side lying towards the sun.

Skeletons of mountains.

In a great many places the skeletons of mountains attest these changes. Near Adersbach, in Bohemia, you pass through a sort of labyrinth of blocks of free-stone, placed perpendicularly, from 100 to 200 feet high, and of a circumference equal to the half of their height. These columns, or rather these square towers, occupy a space of ground a league and one-third in length, and half a league

[m] Bergmann, Géographie Physique, ii. 242.

in breadth. A rivulet meanders amongst them, and loses itself in a gulf. The verdant foliage of trees and shrubs is mingled with the grey masses of the rocks. This labyrinth is evidently the remains of a mountain, the less solid parts of which have crumbled down, and been carried off by currents of water. The famous *stones of Carnac*, which the vulgar regard as a Druidical temple, appears to us only a labyrinth of Aderbach in miniature. Other countries present similar pictures: such as Stonehenge in England, Griffenstein in Saxony, the rocks of Svit-Feene in China, and several assemblages of enormous stones in the Cordilleras of Peru. The primitive nations chose such places, stamped with the impress of divine power, to solemnize the rites which they dedicated to beings of a superior nature.

Combined effects of these causes.

The slow, but continual and combined action of all the causes which we have specified, is followed by the most astonishing catastrophes.

The remains of the mountains called Diableret, in Switzerland, present, it is said, a very picturesque scene; portions of wood and pasturage, which have escaped the common disaster,—rocks, shivered, dismantled, cleft from top to bottom, and seeming to announce new desolations,—torrents, which are forced to scoop out for themselves a new bed, wear away the trunks of birch trees and firs, half buried in their waves. Such are the varied groupes which adorn this theatre of devastation.

It was, according to the History of the Academy of Sciences, in the month of June 1714, but, according to M. Bourrit, and other Swiss writers, the 23d September 1713, that the summits of the Diablerets suddenly fell, and covered the extent of a square league with their fragments, which often form a bed of stones 30 yards and more in thickness. Although several hundred cottages were buried in the ruins, fortunately only 18 persons perished. Cows, goats, and sheep, were the principal victims. The dust which was raised by the fall of the mountain occasioned for some moments a darkness like that of night, although the

event took place at three o'clock in the afternoon, and in fine weather [n].

We have a more satisfactory account of the falling down of a mountain, which took place in 1751, near Sallenche, in Savoy. The naturalist Donati thus describes this event: A great part of the mountain, situated below that which fell down, was composed of earth and stone, not arranged in strata or beds, but confusedly heaped up. The rolling down of these stones, in former times, had left by degrees the principal rock of the greater mountain without support. This mass was composed of five horizontal and distinct strata, the two first were of a slaty and brittle kind, the two following presented to view a shelly marble, cleft transversely in its beds. In the fifth, the slate reappeared, but its laminæ were in a vertical position, and entirely disunited. The waters of three lakes, formed in this last stratum, continually penetrated through the chinks of the mountain. The abundant snow of the year 1751 augmented the force of these waters, and determined the fall of 648 millions of cubit feet of rocks, bulk enough to have formed a great mountain. The fall of this mountain was accompanied by a quantity of dust uncommonly subtile, and which was taken for smoke, because it supported itself in the air for several days. A report was spread that a new volcano had broken out in the midst of the Alps, where the ravages of subterraneous fires had never been known. But Donati, having been sent to the spot, soon dissipated these groundless fears [o].

The sliding of rocks.

There is also another kind of catastrophe, which is not less extraordinary in its causes, than destructive in its effects:—it happens when one bed of earth or rock slides over another bed without breaking, or separating into pieces. Some years ago, the commencement of an event of this kind was observed at Solutré, near Macon. After some great rains, the strata of earth which lay upon the moun-

[n] Bourrit, Description des Alpes Pennines, &c. Ebel, Itinéraire, ii. 26.

[o] Donati, cité par Saussure, Voyages, sect. 493.

tain of Solutré, slid along over couches of calcareous stones, which constitute the body of the mountain. They had already advanced several hundred yards, and the village was about to be buried in ruins, when the rain ceased, and this moving mass of earth was arrested in its progress [p]. A still more astonishing fact of this kind is related: a part of the mountain *Goima*, in the Venetian State, detached itself during the night, and glided along, with several houses, which were carried into the neighbouring valley; in the morning the inhabitants, who had felt nothing, were extremely astonished, when they awoke, to see themselves at the bottom of a valley, and for a long time imagined that a supernatural power had transported them through the air into some distant climate, until, upon examining the environs, they perceived the traces of the revolution which had so wonderfully spared them.

Various disasters are often connected together: inundations originate from the fall of masses of earth, and occasion such falls in their turn.

In 1772, the mountain of Piz, in the marche of Treviso, in the State of Venice, was cleft in two; a part was overturned, and covered three villages, together with their inhabitants. A rivulet, stopped by the rubbish, in three months formed a lake. The remaining part of the mountain precipitated itself on that side, the lake overflowed its banks, and many people perished. Several villages were also buried under the waters [q]. Effects of falling down.

This brief sketch is sufficient to show the difference that exists between a subsiding or falling down, and a shaking of the earth, or earthquake, catastrophes too often confounded by the ancients, and even now by the vulgar. The effects are often the same, but the mode of action and the causes are different. There are fallings down without volcanic shocks, but these shocks often occasion them. The only point of necessary coincidence is, that great rains,

[p] Delamétherie, Théorie de la Terre, vol. v. sect. 1420.
[q] Geography of Gaspari, (in German,) vol. i. p. 370.

which succeed great droughts, equally bring on displacements and earthquakes. They occasion earthquakes, by evolving in the bosom of the earth elastic and inflammable gases; and they occasion the fall of large masses by cracking, softening, and detaching the different strata of the mountains. The ancients imagined that they could prevent earthquakes, by digging in the towns and surrounding country, ditches and deep wells, to give vent to the subterraneous vapours. It is more certain that men may, with a little care, avoid the destructive effects of fallings down. At first, in choosing the site of a town, or of a village, we ought to level the neighbouring heights, and examine the nature of the rocks, whether they are solid and durable, or the contrary; it is then, generally speaking, easy to place the buildings beyond the reach of such accidents. A Greek naturalist foretold to the Spartans the fall of a projecting part of Mount Taygetus, which soon after overwhelmed in ruins a considerable portion of the city of Lacedemon. Canals and drains, to carry off from the mountains their superabundant waters; reservoirs, where these waters may be collected for distribution over the country, to irrigate the fields and to drive machinery; dikes, walls, and perhaps deep ditches, to stop and weaken the shocks of avalanches; these are the barriers which human industry can oppose to such alarming and disastrous occurrences, one of the most salutary effects of which is to awaken our dormant powers, and to heighten our courage, by giving scope for its exercise.

Whether it be possible to prevent or foresee fallings down.

In tracing out terrestrial hydrography, we have already noticed the very considerable force of running water; and the precipitation of parts of mountains, which we have just been describing, serves to exemplify some of its effects. Its action is still more general; the wandering torrents which roll down rocks, and root up forests, the deep stream which gradually undermines the mountains at whose base it flows, the vast and powerful river which shifts at pleasure the place of its bed, and sometimes creates, by the matter it deposits, a Delta of Egypt, and sometimes, by swallowing

Effects of running water.

up extensive districts, forms new lakes, as, for example, the Lake Biesboch in Holland; these are the powers which, set in motion by the hand of nature herself, in whose operations ages are accounted as moments, have been able to produce a very great proportion of the changes which the secondary and ternary soils have undergone.

Excavations in rocks, by water.

We shall now produce some examples of very singular changes, arising solely from the action of running water. Upon Mount *Limur*, in Norway, we see two roads worn in a rock of marble, the one above the other. The marble itself which separates them, and which is only three inches thick, allows you to perceive, through its clefts, a river flowing in the lower road. It appears that the waters of a lake, situate some hundred feet higher, have by degrees hollowed out for themselves these two openings through the rock. It was thus, that the river Gaulen, in the same country, lost itself in 1344, and re-appeared some years afterwards with extreme violence, driving before it the ruins of the subterraneous prison into which it had descended [r].

Mount Jura, and in general all calcareous mountains, present facts of the same kind. The lake of Joux, and that of Grand-Vaux, and many others, have worn in the rock the funnels through which their waters flow. Sometimes, when the sides of the passage which the waters had made for themselves, become in part worn away and excavated, the roof falls down; it then forms an outlet, cut perpendicularly, through which the waters escape, as near Orgelet, upon the road of Saint Claude [s]; or the mouth of the valley, blocked up by the rubbish, forces the waters to give birth to a lake, such as that of Sillan, near Nantua [t].

Funnels.

Another singular phenomenon occurs in the funnels with no outlet, called in Sweden *Giants' Cauldrons*. These are circular excavations, sometimes of a spiral form, having their sides very smooth, situate for the most part on the

[r] Pontoppidan, Natural History of Norway.
[s] Bertrand, Nouv. Principes de Géologie, p. 175.
[t] Ibid. p. 178. Comp. Saussure, Voyages, sect. 384.

sides of mountains, and frequently containing in the centre a rounded stone. The traveller Kalm observed these hollows in the United States, near Fort Nicholson. Several examples, observed in Switzerland and in Siberia, might be mentioned, but they are to be met with only in sulphated calcareous rock [u]: on the contrary, those of Sweden and the United States exist in granite. According to Bergmann, they have been formed by running waters, which had become engulphed there, and had imparted a rotatory motion to a stone detached from a neighbouring rock [x].

In admitting this explanation, the giants' cauldrons would incontestibly prove, that there was a time when the granite was not harder than common limestone or gypsum.

Drying up of the lakes.

There are many lakes which hold in solution saline, earthy, metallic, and bituminous substances: these substances form sometimes simple deposites; at other times they are thrown down to the bottom of the lake, by chemical precipitation. Several causes may here concur. The different gases and acids with which the waters of these lakes are charged, may give rise to crystallizations; a cooling in lakes which possess a certain degree of heat, may also have the same effect. It is certain, that the remains of the beings that live and die in these waters, form beds of calcareous earth. Trees and vegetables, which are carried along by the waters, form floating islands, which, by degrees, unite together, and either cover the lakes with a crust of earth, or, by sinking, raise up the bottom. We must add, that the more a stagnant mass of water loses in depth, the more it evaporates; for the evaporation of water is always in the direct ratio of its surface, and in the inverse ratio of its depth, as experiments have proved. There are in all mountainous and marshy countries numerous instances of small lakes which have been dried up by one of these causes; we may therefore safely infer, that the same phenomena

[u] Patrin, Histoire Naturelle des Minéraux, iii. 201. Saussure, Voyages, sect. 1238.

[x] Bergmann, Géog. Phys. ii. 228.

have taken place upon a larger scale, and that the formation of several extensive plains is to be ascribed to the drying up of inland seas, or great lakes; as for example, part of those which border on the Caspian Sea [y].

The damming up of a lake commences by confining its basin, but the lake always receiving the same quantity of water, it necessarily overflows, and if it happens to discharge itself into other inferior lakes, it may produce successive overflowings, which change the surface of the surrounding country. These efforts would be more violent if a sudden thaw, and a superabundance of water, took place at the same time. The waters in this case would perhaps be impelled by so impetuous a force, as to overthrow every thing they met with in their course, and make large excavations in the chains of mountains, and thus form great valleys. This idea was developed by Sulzer, and carried to extremes by Lamanon [z]. It occurs very naturally, when one considers the great lakes of North America, which flow into one another, and finally into the river Saint Lawrence. If the soil which borders the Ohio, and where we find the bones of the mammoth, is impregnated with salt; if the plain which surrounds the river of the Amazons, is, as is said, entirely composed of soft earth, without any stones; if we find in the plain of Crau and in Dauphiny the same pebbles and rounded flints, as upon the borders of the Lake of Geneva, then all these circumstances may be accounted for on the supposition of the overflowing of the interior lakes;—but historical certainty is wanting, and will always be wanting, to these hypotheses. It is, besides, very certain, that valleys must have existed before the flowing of the waters could take place. All, therefore, which can be conceded to this theory of the excavation of the earth by currents of water, must be limited to effects which regard only the superficial strata.

Breaking down of dams.

[y] Delamétherie, Théorie de la Terre, sect. 1417.

[z] Lamanon, Journal de Physique, 1780, December, p. 471.

Do the waters of the sea diminish?

We come to a question which has greatly engaged the attention of physical geographers: the diminution of the waters of the sea.

Let us begin by defining the subject of inquiry. We have nothing to do with those marine or other fluids, which at different epochs covered the globe, and in which lived innumerable shell fishes, sea petrifactions, and polypuses, which we have seen upon the summits of the highest mountains. It is plain that these fluids have disappeared; but the slow or rapid manner of this disappearance, and its internal or external causes, can be known to us only by conjecture. Man existed not at the time of those revolutions which have heaped up on one another the remains of the sea, and of fresh water animals. The question is only concerning changes which the sea of the terrestrial globe may have undergone since the last revolution, which has created our existing continents. To the question thus limited an answer may be given.

A very long expereince, that of more than twenty centuries, enlightened by the torch of history, seems to prove that the present sea, considered as to its entire quantity, is in a state completely stationary, so that the evaporation of its waters is equal to the quantity with which the rivers augment it, and its extent is neither diminished nor enlarged. But local circumstances, as for example the clearing of waste land, the destruction of forests, the choking up, or the turning away of the channels of rivers, may for a certain time alter the level of some interior seas. Other temporary or local causes may produce in the same ocean, not an augmentation or diminution of volume, but small oscillations, which, by subverting the equilibrium of the waters, occasion on one side the little retirings of the sea, consequently the formation of new ground; and, on the other side, little invasions of the sea upon the earth: these changes mutually compensate each other, and are limited, and too variable, to have any sensible influence upon the form of great continents.

The present sea endeavours in two ways to change the form of its banks: it creates new lands by depositing sand, gravel, shells, and marine plants, by casting up and by retaining the mud, and other substances brought down by the rivers; by undermining the mountains which border it, which causes them at last to fall; by retiring of itself, either because the rivers bring to it a diminished supply of water, or, because on another side, it has overflowed some ground over which it has spread a part of its waters. It has invaded the ancient shores, by washing them away, or by rising above their level, when from any cause whatever, its basin has been elsewhere confined. The seas of Europe, being the best known, will furnish the best proofs of our assertions. Let us begin with the Mediterranean.

Manner in which the sea produces changes.

We have seen, that by taking in Homer the word *Egyptos* for the name of the river, and not for that of the country [a], we may dispense with admitting, that the sea has filled up the supposed ancient gulf, which penetrated into Egypt as far as Thebes, and which separated by one day's navigation the island of Pharos from the mainland, as has been commonly affirmed. Some less considerable additions have, without doubt, been made to the land since the time when Herodotus gave us the first description of the country; but these are owing, less to the mud which the river carries down, than to the winds which bring with them the sands of the neighbouring deserts. This is what daily happens upon the coasts of Egypt. The port of Alexandria is dammed up, the town of Damietta, whose walls, in the time of Louis IX. were washed by the sea, is now at a considerable distance from it. As a kind of compensation, the lake Mengalah appears to be formed, either by the overflowing of a branch of the Nile, the cleaning of which has been neglected, or by an irruption of the sea [b].

Changes in the eastern part of the Mediterranean.

Along the eastern coasts of the Mediterranean and its gulfs, there is but little increase of the land. The island

[a] See the description of Egypt in a subsequent volume.

[b] Shaw's Travels, vol. ii. p. 173, 188. Tellliamed, (De Maillet) sur la diminution de la mer, &c.

of Tyre, however, has been united to the continent by a more powerful hand than that of Alexander. At the mouth of the river Pyramus in Cilicia, a deposit of sand has extended the modern coast six miles beyond the ancient; and similar effects have taken place at other points on the southern shore of Asia Minor, where the coast is flat[c]. The Meander has, by little and little, filled up the valley into which it flows, and which was formerly a gulf. The inhabitants of Miletus, and of Ephesus, have several times changed the situation of their towns, by following the sea, which retired from their walls. On the coast of Greece, a great many small islands, situated in front of the openings of the rivers, are joined to the mainland [d].

Changes in the Gulf of Venice.

In the gulf of Venice, very remarkable changes have taken place. Ramazzini having observed that all the country round Modena is suspended over a subterraneous lake, and that a great number of shells are to be found there, is persuaded that Lombardy has, in a great measure, been formed by the combined deposites of the Po, and of the sea. All that is certain is, that the Po in former times committed great ravages, by inundating often whole provinces: it has been confined by strong dikes, but by renewing from time to time these embankments, which preserve the country from total submersion, the bed of the river has been elevated, so that the level of the waters of the Po is now raised several feet above the lands which surround it.

The environs of Ravenna, Aquileia, and Venice, present facts more uniform and better established. There is no doubt, according to the observations of Manfredi [e], that the grounds near Ravenna has sunk to such a degree, that the pavement of the cathedral is only six inches above the level of high water; but, at the same time, the land is extended in such a manner that this town, formerly situate in the midst of marshes, and canals, and furnished with an

[c] Beaufort's Account of Caramania, p. 298.

[d] Strabo, lib. ii. passim. Plin. Nat. Hist. ii. cap. 89.

[e] Manfredi, De Auctâ Maris Altitudine, in Opusc. Bononiens. ii. 120.

excellent port [f], is now three Italian miles distant from the sea, and surrounded by meadows and fields. The Venetians are very much afraid of seeing their canals dry up, and yet the ground on which Venice stands is a little sunk. Aquileia was once close to the sea. It is alleged that the sea, on the other hand, makes encroachments upon the coasts of Istria and Dalmatia. Columns, and pavements in Mosaic, and urns, are there found under the waters.

Changes in the western part of the Mediterranean.

The western coast of Italy presents within a small space two phenomena of contradictory appearance. The Pontine marshes now cover part of the *Appian Way*, whilst in the mouth even of the Tiber, we perceive land which was not there in the time of the ancient Romans. It is not, however, the sea which has covered the Appian Way, but the rivers, which the negligence of the modern inhabitants has suffered to be choked up at their mouth. In the same way, if the renowned villas of the ancient Baiæ are now found buried beneath the water, the reason is that these edifices, once the abodes of luxury and ostentation, were built at the first in the midst of the sea [g].

Upon the coasts of Spain and of France, the Mediterranean has receded. Aigues-Mortes, in Languedoc, was, in the thirteenth century, close to the sea, but at present it is two leagues distant [h]. From the mouth of the Rhone to Agde, the sea has lost ground, or has retired. The port of Barcelona becomes every day less deep. Thus, without entering into a longer detail, we may say that the sum of known additions made to the land on the shores of the Mediterranean, appears to be more considerable than the sum of the encroachments of the water. But, on the one hand, we are totally unable to compare the modern and ancient states of the coasts of Africa; and, on the other hand, there are upon the Mediterranean a vast number of celebrated harbours, which preserve exactly the same level

[f] Bianchi, Specim. æstus Marini. Moro, des Changemens de la terre, ii. ch. 25.

[g] See Peintures d'Herculaneum, tom. iii.

[h] Strabo, V. 216, edit. Almelov.

of waters as in the time of the ancients. Marseilles, Genoa, Syracuse, Navarin, or Pylos, and twenty other places, are found in the same situation. The ruins of Herculaneum touch the sea, so did the town itself in the time of Strabo; there is, therefore, no reason for supposing a general diminution.

Changes in the Atlantic Ocean.

The Atlantic Ocean has made some additions to the land upon the coasts of France, and has contributed to raise the level of those sandy plains which reach from Bourdeaux to Bayonne; several bays have been filled up, and the Adour has been obliged to seek a new opening into the sea. A district between La Rochelle, and Lucon, and in general all the *marshes of La Vendée*, have been gained from the sea [1]. The small bay where Mount Michael is situate, between Bretagne and Normandy, appears to be equally drying up; but near Dob the sea has resumed possession of those lands which had formerly belonged to it.

Changes upon the coast of Holland.

Varenius, Lulof, and other geographers, have described the quantities of soil left by the German ocean upon the coasts of Holland. A number of effects of different kinds are visible here, which all tend to the same result; and we see, above all, a striking example of those changes to which the action of the sea upon the land appears to be subject. In the remotest periods to which history extends, these countries were immense marshes, for which the sea and the rivers contended together. The first deposited sand, the second mud: thus were formed the more elevated grounds which were in some measure habitable. These grounds, however, being sometimes covered with water, and sometimes left dry, belong equally to both elements. Human industry gave a steady direction to the wandering course of the rivers, checked the fury of the waves by immense dykes, and thus created a country even in the bosom of the waters. But there remain lakes, bogs, and marshes: the rivers silently undermine these ill-consolidated grounds; the sea penetrates them through the large openings of the rivers.

[1] La Bretonniere, Statistique de la Vendée.

Several great tides were the epochs of dreadful disasters, of which the following are the most remarkable.

The *Zuyderzee* was anciently nothing but a lake of trifling extent, which flowed into the sea by the river of Ulie, (the *Flevum* of Tacitus,) and considered as a branch of the Rhine. About the year 1250, the sea made an irruption into it. Vast tracts of land, which the running waters apparently had undermined, gave way, and thus the Zuyderzee was formed. The gulf of *Dollart*, between West Friezland and the province of Grœninguen, was, in 1300, a fertile canton, covered with delightful meadows. In 1421, the united force of the sea and of the rivers, destroyed, near Dort, 72 considerable villages, with 100,000 of the inhabitants, (as it is said,) and formed the lake of *Biesbosch* [k].

The Danish coasts of Sleswick and Holstein present a spectacle nearly similar. There the sea has both lost and gained. The island of *Nordstraud* was swallowed up in 1634; that of *Heligoland* sustained great damage, in the 13th century. On the other hand, the sea brings to the shores of the main land a great quantity of greasy mud, bluish clay, and sand; and when these substances have acquired some consistency, the ground is enclosed with dykes. The soil thus formed becomes so fertile, that in a very few years it indemnifies the cultivators for all their outlay. Upon the coasts of Jutland, in the district of Thy, the sea has filled up with sand several gulfs, which once afforded retreat to pirates, according to the ancient history of the north; and it has probably formed the isthmus that now separates it from the gulf of *Limfiord*, which seems to have been formerly a strait. All the western and northern coast of Jutland, (from 55 degrees 24 minutes, to Cape Skagen, 57 degrees and about 40 minutes,) appears to owe its formation to the sea, which by accumulating sand, has made an unbroken coast of what was once a chain of islands.

Changes upon the Danish coasts.

The inconsiderable changes which have taken place in

Diminution of the Baltic.

[k] Lulof, Introduction à la Géographie-Physique, en Hollandais, § 422, 77.

Physical Arguments.

the Baltic, by no means prove a general diminution of the waters of that sea [l]. Naturalists have considered the shells and other remains of animals, as evidences of this general diminution; while historians have endeavoured to prove it by the damming up of ancient harbours and straits. These two arguments evidently relate to two different epochs. We have seen that all the remains of animals belong to an age when man did not exist. As to the records of history, which, with regard to Sweden, commenced only with the 9th century, there have been upon some coasts of Sweden, accumulations of sand and gravel, particularly among those labyrinths of rocks by which it is in a great measure surrounded. These accumulations are owing to the violence of the currents, which at the same time are very variable; but the gains and losses of this sea compensate each other. If the strait opposite Swedish Pomerania is filling up towards the north, it becomes every day deeper towards the east. In general, we should say with Browallius [m], that if a thousand observations proved the diminution of the waters, one single observation of the contrary, would be sufficient to reduce these observations to the limits of a local fact. But there is not one: there are a hundred contrary observations, which prove that there has been no general depression in the level of the Baltic sea. Oaks of the age of three centuries, growing on low lands close to the sea; castles which have existed for ages in places which, according to the hypothesis of Celsius, must have but lately arisen under the waters,—these are the facts which have been triumphantly opposed to the computed results of the advocates of desiccation. Browallius points out a number of places even upon the Swedish coasts, where the sea has be-

[l] Linnæus, de Telluris Habitabilis incremento. Amœnit: Acad. ii. 430. Id. Voyage de Westrogothie, d'Acland, de Scanie, &c. Ol. Celsius, Observat. Acad. scienc. Succ. 1743, p. 33. Dalin, Hist. de la Suède, pr. face. Bergmann, Géographie Physique, 5e section, chap. iii. Ferner, Discours contenant l'Histoire de la Dispute sur la Diminution des Eaux.

[m] Browallius, Recherches Physiques et Historiques sur la prétendue Diminution des Eaux, &c. Stockholm, 1756.

come deeper. I should add, that the German geographers commonly assert the same thing, as far as relate to the German coasts of that sea

The historical arguments in favour of the diminution of the waters of the Baltic, have been equally overthrown. Some have insisted upon the vague language of Grecian and Roman geographers, who represent Scandinavia as a large island; but if the sea had, since the time of Pliny, sunk sufficiently to make the soil of Finland, elevated from 500 to 1000 feet, emerge from under the waters, it would then follow that Mecklenburgh Holstein, the wastes of Hanover and of Westphalia, and the island of Batavia, now called Betuwe, grounds elevated only from 2 to 400 feet, must have been equally under water. It is, however, certain that the Roman armies carried on war there, and that Ptolemy, at the commencement of the second century, describes those regions in such a manner, that we recognize their existing forms with very few changes. Historical Arguments.

The charts of the middle age prove nothing in favour of the diminution of the waters. In the convent of St. Michael de Murando at Venice, there is preserved a map of the world, which was made by one of the monks, whose name was *Mauro*. This chart had been made with the assistance furnished by a person called P. Quirini, who, in 1431, had sailed to Trondheim, and from thence had traversed Sweden by land. The Baltic is there seen to be more extensive than it is now. But who does not know that upon all the old charts, unskilful designers and engravers have rounded the capes, contracted or extended the islands, and marked out the seas according to their own fancy? How can we allow so great authority to *general* maps, constructed in ages in which there was not one *special* map projected with any care? The decisive argument in favour of the stationary condition of the Baltic, for twenty centuries, is the identity of so many names of provinces and districts, known in the ancient history of the north, with those which are still applied to the same places; the resemblance of the country as it now exists, with that which we Maps of the Middle Age.

read of in ancient history; the ancient celebrity, in Scandinavia, of countries which could not even have existed, if we admit the hypothesis of Celsius, the absolute silence of popular traditions, and of ancient Scaldic poetry, which would not have failed to preserve some brief recollections of so great and so memorable a change. In short, if the Baltic sea has diminished, such an occurrence must be referred to those remote periods, involved in the obscurity of ages, when perhaps some very great catastrophe caused a general drying of the ocean, which covered a great part of the earth. But if such a change has taken place, it is certainly an event altogether unconnected with the order of nature under which we live, and with a successive diminution of the present sea [n].

Diminution of the Baltic, by the clearing of new grounds.

A less bold hypothesis may be proposed with regard to the Baltic sea. We may attribute solely to the clearing of Finland, and some extensive Russian provinces, as well as to the successive destruction of forests in the north, a successive diminution in the quantity of river water flowing into the Baltic sea; consequently this sea, once a little more elevated than the northern sea, and that of the ocean, will have sunk to the general level of other seas. Not only does the clearing of the ground sometimes diminish, and at other times increase, the quantity of running water in a country, but it also changes the atmospherical constitution; it renders it, generally speaking, warmer, consequently it augments the evaporation which daily takes place at the surface of the waters. We think that this explanation will be sufficient to account for all the changes which are observed in the level of inland seas.

Local changes. Example.

We have seen the effects produced by the Baltic sea: we have seen the island of Hveen, the celebrated residence of Tycho Brahe, diminished by the violence of the waves; whilst a few leagues from thence, near the southern point

[n] Bring (since named Lagerbring) de Fundamentis Chronologiæ Sueo-Gothicæ, p. 18, 50, 55, 73, 76. Rhyzelius, Episcopia Sueo-Gothica, ii. 118. Schm, Depuis ce de l'Origine des Peuples, p. 11, &c

of Scania, an island is formed, composed of sand: some grass having taken root there, has raised and consolidated it; and it increases every year, without any sinking of the neighbouring sea. The straits through which lakes and inland seas discharge themselves, may be compared to large rivers, which often experience local changes upon their banks.

Effects of the frost.

The frost contributes to elevate certain parts of the Baltic coast. When the lakes and large rivers are frozen, the porous earth which borders them, forms, with the neighbouring water, one single mass of ice. If now, waters which are not frozen, happen to join the mass also not frozen, of either lakes or rivers, the crust of ice must be raised, and the frozen earth must be raised along with it; the void which is formed below these raised masses is filled by mud and gravel from the bottom of the lakes and rivers. Thus after the thaw, the porous earth is left lying on a more elevated level than it had at first. These facts may be observed every year in East Bothnia [o]. The marine ice, suddenly broken by some oscillation of the sea, lifts up whole rocks, and carries them further upon the land. In Sweden, there are two rocks which owe to this cause a more elevated position than they once had [p]. Kalm, who has made such accurate observations on North America, says, that there are considerable additions made to the land in the province of New Jersey, along the rivers, but he attributes them to the clearing of the country. Uncultivated ground covered with rocks, moss, and briars, is proof against the influence of running water; whilst cultivated land presents to the action of the water a surface rendered moveable by the plough, and decomposed by the air and the sun, the small and light particles of which are easily carried along by the waters. This observation appears to us to be very correct, and perfectly conformable to what we see

Observations upon Western America.

[o] Bergmann, Géographie Physique, ii. 214, *sqq.*

[p] Runeberg, Dissertation, &c. dans les Mém. de l'Académie de Stockholm, 1765.

in the north, especially in the clayey and muddy ground[q]. It is useless to enter into a minuter detail concerning other quarters of the world. The augmentations of soil near *Tehama* in Arabia, and the alleged submersion of the *Bridge of Adam*, which, it is said, joined the island of Ceylon to India, would furnish us with a decided contrast. From the *Voyage of Nearchus* we should learn, that notwithstanding the immense tides, the coasts at the mouth of the Indus have not been sensibly changed since the time of Alexander. Were we to believe the Chinese annals, we should on the other hand have clear proofs of the progressive desiccation of the globe. But the coasts on the north-west of America, would present us with traces of the encroachments of the ocean. In short, all the facts that have been collected, when carefully examined and carefully weighed, bring us to no other conclusion than this—that the *existing sea is completely stationary*, and that its level falls and rises from local and temporary causes, without any change in its general volume.

General conclusion.

If, notwithstanding this historical truth, we find, on the continent, and even at a considerable height, anchors and wrecks of vessels, we can explain these phenomena by admitting a tradition recorded in the inspired pages of Moses, and ably defended by Deluc. When the soil of our present continents formed the bottom of the ocean, there existed another continent peopled with inhabitants; a continent which disappeared in consequence of a great catastrophe, which at the same time left dry the existing habitable earth. The antediluvians, therefore, navigated above the level of our present fields: they pursued the whale where we now reap our harvest; they cast anchor upon our mountains, which were then rocks and islands in the bosom of the sea. Whatever may be the fate of this hypothesis, Deluc has clearly shewn that these ancient wrecks cannot establish a progressive diminution of the existing sea[r].

Remarks upon the old wrecks of ships.

[q] Kahn, quoted by Browallius, § 103.

[r] Deluc, Lettres Physiques et Morales, ii. Lettres 89 et 90.

Let us now contemplate the ravages of another element. The name of *volcano*, taken from that which the Romans gave to the God of Fire, now designates those mountains which vomit forth flames, smoke, and torrents of melted matter. The chimney through which the smoke and melted matter issue, terminates in a vast cavity in the form of a truncated and inverted cone. This mouth of the volcano is termed the crater. Volcanoes.

The eruption of a volcano is a most frightful and most majestic phenomenon. The signs which are the forerunners of the explosion, announce that the invisible combat of the enraged elements has already commenced. These are, violent movements which shake the earth afar off, prolonged bellowings, subterranean thunders, which roll in the sides of the agitated mountain. Very soon the smoke, which is almost continually emitted from the mouth of the volcano, increases, thickens, and ascends, under the form of a black column. The summit of this column, yielding to its own weight, sinks down, becomes rounded, and presents itself under the appearance of the head of a pine tree, having the lower part for its trunk. This hideous tree does not long remain immoveable: the winds agitate its blackened moss, and disperse it in branches, which form so many trains of clouds. At other times the scene opens with more brilliancy. A stream of flame rises beyond a collection of clouds, keeps immoveable for some time, and then appears like a pillar of fire which rests upon the ground, and threatens to set the sky in a blaze. A black smoke environs it, and from time to time intercepts the dazzling brightness. A number of lightnings appear to flash from the midst of the burning mass. On a sudden, the brilliant cascade seems to fall back into the crater, and its fearful splendour is succeeded by profound darkness. The effervescence, however, goes on in the interior abysses of the mountain; ashes, dross, and burning stones, are projected in diverging lines, like the spouts of fireworks, and fall around the mouth of the volcano. Enormous fragments of rocks appear to be heaved against the skies by the arms of the new Titans. Description of volcanic eruptions.

A torrent of water is often thrown out with impetuosity, and rolls, hissing over the inflamed rocks. There is then raised from the bottom of the crater a liquid and burning matter, similar to metal when in fusion. This fills the whole of the crater, and reaches to the very edges of the opening. An abundant quantity of dross floats on its surface, which ultimately appears and vanishes as the liquid mass rises or falls in the crater where it seems to boil. This scene, of so majestic a character, is but the prelude of real disasters. The liquid matter overflows, runs down the sides of the volcano, and descends to its base. There it sometimes stops, and appears like a fiery serpent recoiling upon itself. More frequently it dilates itself, and gushes out from beneath a kind of solid crust which is formed upon its surface: it advances like a large and impetuous river, destroys whatever it meets with in its course, flows over those obstacles which it cannot overturn, passes along the ramparts of the shaken cities, invades a space of country of several leagues in extent, and transforms in a moment flourishing fields into a burning flame. Equal ravages may be sustained, though the liquid matter called *lava*, does not issue exactly from the top of the volcano: it is sometimes too compact and too weighty to be elevated to the summit; its violent efforts then occasion new ruptures in the side of the mountain, through which the igneous torrent rushes out [a].

Ravages of the lava.

Geography of volcanoes. Great volcanic chain of the globe.

A great chain of ignivomous mountains stretches around the great ocean. Terra del Fuego, Chili, Peru, all the chain of the Andes, are full of volcanoes. We distinguish in Peru, those of Arequipa and of Pitchinca; and that of Coto Paxi, whose flames, in 1738, rose higher than 2000 feet, and whose explosion was heard at the distance of 120

[a] Plin. jun. Epist. lib. ii. p. 16. Pindar. Pyth. I. v. 35—50; Virg. Eneid. III. v. 571—582. Claud. Rapt. Proserp. I. v. 151—176. Della Torre, Histoire du Vésuve, en Italien. Hamilton, Lettres sur les Eruptions du Vésuve. Dolomieu, Memoires sur les iles Ponces; Id. Voyage aux Iles Lipari, &c &c

leagues, if we may give credit to the Spaniards. *Chimborazo*, the highest mountain of the globe, is an extinguished volcano; and there are a great many others. Humboldt has seen the smoke of Antisand rise 18,000 feet[t]. If we pass the isthmus of Panama, we find the volcanoes of Nicaragua and of Guatimala. Their number is infinite: there are some which are covered with perpetual snow, and which consequently are elevated to a great height.—Then come those of Mexico, properly so called; namely, Orizaba, Popocateipetl, 16,626 feet high; Jorullo, which first broke out in 1759, and several others, all situate under the 19th parallel of latitude[u]. California contains five volcanoes, that are now burning. There can be no doubt, according to the accounts of Cook, la Perouse, and Malaspina, that there is a number of very considerable volcanoes on the north-west of America. Mount Saint Elie is nearly 16,800 in height; these volcanoes form the intermediate link between those of Mexico and those in the Aleutian islands, and the peninsula of Alaschka. These last, which are very numerous, both extinct and burning[x], serve to continue the chain towards Kamtschatka, where there are three of great violence. Japan has eight; and the island of Formosa has several. The volcanic belt now becomes immensely wide, and embraces the Philippine islands, the Marian or Ladrones, the Moluccas, Java, Sumatra, the isles of Queen Charlotte, the New Hebrides, and, in short, all that vast Archipelago which forms the fifth part of the globe. These volcanoes will be particularly noticed when we describe in detail these islands in which they are found[y].

Volcanoes of the Indian seas.

The other volcanic chains are far from being of so great extent. There is perhaps one in the Indian Sea. The islands of Saint Paul and Amsterdam, the formidable volcano in the island of Bourbon, and the jets of hot water

[t] Humboldt, Tableau des Régions Equatoréales, p. 121.

[u] Humboldt, Essai sur le Mexique, liv. iii. ch. viii. p. 253.

[x] Gmelin, Description de la Russie, i. 258.

[y] Struyck, Introduction à la Geographie, (in Dutch) p. 67.

in the island of Madagascar, are the only known links of this chain.

The gulf of Arabia flows at the base of the volcano of *Gebel-Tar*. The neighbourhood of the Dead Sea, and the whole chain of mountains which runs through Syria, have been the theatre of volcanic eruptions. We may be allowed to connect these two facts.

Volcanoes of Europe.

A vast volcanic zone surrounds Greece, Italy, Germany, and France. The celebrated revolutions of the Grecian Archipelago, and those new islands produced by submarine explosions are well known. The summits of Mount Etna are next descried; this mountain has burnt for 3300 years [z], and it is surrounded by extinguished volcanoes which appear much more ancient. The islands of Lipari seem to owe their origin to the volcanoes which they contain. Vesuvius has not always been the only igniyomous mountain in the kingdom of Naples, another still larger, but extinguished, has been discovered near Rocca Fina [a]. The Solfatara is ranked under the same class. The Ponce islands, or island of Ponza, are of volcanic origin; the catacombs of Rome are excavations from the lava. Tuscany abounds in hot and sulphureous springs, and other indications of volcanoes. Arduini observed in the environs of Padua, Verona, and Vicenza, a great number of extinguished volcanoes. Dalmatia has several. It was long suspected that a district in Hungary nourished subterraneous fires in its bosom; the eruption of a volcano has recently evinced the truth of the conjecture. Germany contains a great number of extinguished volcanoes; the best known of which are those of Kamberg in Bohemia, Transberg, near Gottingen, and those near Bonn and Andernach, upon the borders of the Rhine. The southern part of France is full of extinguished volcanoes, amongst which Mount Cantal, the Puy-de-Dome, and Mount d'Or in Auvergne, are the most conspicuous [b].

[z] Guénau, see the French part of the Collect. Academ. vol. vi. p. 489.

[a] Scipione Breislack, Topographia Campaniæ; and le Journal de Physique l'an viii.

[b] Beroldingen, Volcans Anciens et Modernes, considér s physiquement, &c. Manheim, 1791, 2 vols. (in German.)

The Western is not like the Great Ocean, encircled by a chain of ignivomous mountains, but it contains in its bosom several groupes. If the principality of Wales, the island of Staffa, and some parts of Scotland and Ireland, exhibit only equivocal proofs of the existence of extinguished volcanoes, Iceland presents to our view its Hecla, its Kotlouguia, and several other volcanoes, which rise from the midst of perpetual snow. This volcanic focus is one of the most active in the globe; the very bottom of the ocean is, in these regions, agitated, and the waves often heave up whole fields of pumice stone, or with convulsive throes give birth to permanently new islands. Several circumstances lead us to suppose, that there are some volcanoes in the interior of Greenland. That frozen country experiences the shocks of earthquakes. Volcanoes of the Atlantic Ocean.

The middle of the Atlantic Ocean conceals another volcanic focus, of which the Azores and Canary islands have felt the effects. The Peak of Teneriffe, which is 11,400 feet, is the most elevated volcano in the old world. It is very probable that Lisbon has, in its vicinity, a submarine volcano.

The Antilles probably contain a whole system of volcanoes, parts of which are recognised in Jamaica, Guadaloupe, and Grenada.

We may also mention some volcanoes, which are detached, or which belong to groupes little known. Such are Mount Elburtz in Persia, the extinguished volcanoes of Daourie, discovered by Patrin; perhaps some volcanoes to the north of China. That which is seen in Fuego, one of the Cape Verd islands, and those which the Portuguese authors point out in Guinea, Congo, and Monomotapa. Scattered volcanoes.

It follows from this general survey of volcanoes, that they are most numerous in the neighbourhood of the sea, and in islands. Nevertheless, there are many, however, which do not appear to have any communication with the sea. Another general fact is, that the craters of volcanoes burst forth in all kinds of granitic, schistous, argillaceous, primitive or secondary rocks; but there is nothing to throw General results.

light upon another question much more interesting, in what species of rock or earth the focus of these immense and awful fires is placed? The solution of this question involves that of the origin of volcanic fire, which has been so long and so keenly agitated.

Origin of volcanic fire.

Rouelle, Desmarets, and other philosophers, attribute the origin of volcanic fire exclusively to the inflammation of bitumen, pit-coal, fossil wood, and turf, or peat. An explanation more generally received has been proposed by Lemery, who ascribed the volcanic phenomena to the spontaneous inflammation of pyrites, and who, by a striking experiment, has rendered this hypothesis highly probable. He formed a mixture of 50 pounds of iron-filings and sulphur, which, after moistening it, he buried in the ground at a certain depth; the mixture became gradually heated, and at last took fire with a great explosion [c].

Most naturalists combine these two opinions, considering pyrites as the foundation and cause of volcanic fire, while the vast masses of bituminous and carbonaceous schists which are often met with stratified in the same rocks, serve as fuel to the subterranean fire, which becomes extinguished when it can find no more nourishment [d].

Difficulties, however, still remain. Fragments of granite, which the volcanoes project, and which seem to indicate the place of their focus under primitive rock itself; the long period of the activity of certain volcanoes; the impossibility that the neighbouring earth could furnish such copious ejections without becoming excavated, and sinking down; the inconceivable force with which heavy masses of matter are projected to immense heights; and, besides the astonishing force, and the sudden explosion, the peculiar nature of volcanic fusion, which rarely produces vitrification, and which appears oftener to digest and concoct than to burn; these are circumstances which have led not a few

[c] Memoir de l'Acad 1700. This experiment has been repeated in Holland. Journal de Physique, 1794, 5me cahier.

[d] Bergmann, Geographie Physique, ii. 214, 220. Pallas, Observ. sur les Mont. p. 54. Delametherie, Theorie de la Terre, §§ 1011, 1020.

naturalists, well versed in such observations, to suppose that the reservoirs of volcanoes exist at a very great depth, and that their activity is owing to more general causes, such as electricity, or the elastic gases inclosed within the bosom of the globe [e].

Deluc thinks that the focus of volcanoes is in a certain residue of the primitive fluid, in which, according to him, the earth was formed, and that the volcanic fire is of a chemical nature very different from that of all known fires [f].

Earthquakes.

We come to a dreadful phenomenon intimately connected with volcanic eruptions—earthquakes, those convulsive movements which shake the surface of the earth, whether in a *horizontal* direction, with undulations similar to those of the sea, or *vertically*, when a part of the ground is raised up, and the other part sinks down as into a gulf, or *circularly*, when ponderous masses of rocks and earth revolve as it were on a pivot. These are the three kinds of motion distinguished by Italian writers who are well acquainted with these phenomena [g].

Description of their effects.

Earthquakes produce the most calamitous effects: they often change the surface of a country in such a manner that it is difficult to recognise it. Enormous gaps appear to discover to the eyes of the living the empire of the shades. These fissures emit bluish flames, and deadly vapours; in the course of ages they form new valleys. In other places mountains are swallowed up or overthrown; often detached from one another, they glide along upon the lower ground, and as the force with which they are impelled redoubles at every moment, these ambulatory rocks bound over both valleys and hills. Here the vineyard descends from its height and settles in the midst of fields of corn;

[e] Dolomieu, Journal de Physique, an. vi. p. 408. Faujas St. Fond, sur les Volcans du Vivarais, id. Minéralog. des Volcans, id. Essai de Geologie, ii. 402.

[f] Deluc, Lettres à Blumenbach, &c.

[g] Bertrand, sur les tremblemens de la terre. Dolomieu, Memoirs sur le tremblement de la Calabre. Hamilton, &c. &c. Bartels, Lettres sur la Calabre.

there, farms with their gardens, lifted without separating, become attached to distant villages. In one quarter, new lakes are formed in the midst of the earth, in another, rocks hitherto invisible, suddenly rear their wet summits from the bosom of the foaming sea. Springs are stopped, rivers disappear and lose themselves under ground; others, choked up by fragments of rocks, spread out into vast marshes. New springs gush out from the shattered sides of the mountain, incipient rivers struggle with youthful impetuosity, and endeavour to hollow out a channel for themselves amid the ruins of towns, palaces, and temples.

Presages of earthquakes.

What makes earthquakes still more dreadful is, that there are no signs which unequivocally indicate either their approach or their termination. They happen at all seasons, and under every constitution of the atmosphere. A subterraneous noise indeed is their infallible forerunner; but it is scarcely heard before the earth gives way. Animals, particularly horses, dogs, and fowls, shew by their terror a presentiment [h] of its coming. The barometer falls extremely low.

Earthquakes act with astonishing rapidity. It was one single shock which, on the 5th February, 1783, overthrew Calabria, and destroyed Messina in less than two minutes. But these agitations are sometimes repeated for the space of months and whole years, as in 1755.

Direction of earthquakes.

The *direction of earthquakes* is one of the most remarkable facts in physical geography. Sometimes we remark a central point where the shocks are most violent, and this centre sometimes changes its place, as if the subterraneous force rebounded from one point to another, sometimes we can distinguish a certain line along which this force seems to move. The sphere of such a revolution seems often to embrace a fourth part of the terrestrial globe. The earthquake which caused such devastations at Lisbon was felt in Greenland, in the East Indies, in Norway, and in Africa. That of 1601 shook all Europe and a part of Asia. In

[h] Seneca, Judit. nat. vi. 1, 29.

1803 the shock was felt almost simultaneously at Algiers, in Greece, at Constantinople, Bukarest, Kiow, and Moscow.

No part of the globe appears to be exempted from these terrible effects. The Alps contain no trace of a volcanic agency, and yet they are often shaken by earthquakes[1]. The silver mine at Konigsberg in Norway was first opened up to view by a shock in 1603; the frozen zone also is ever subject to earthquakes. Greenland feels frequent shocks; and in 1758 Lapland experienced violent commotion. Generality of this phenomena.

The sea often, but not always, shares in the convulsions of the earth. In 1755, the waters of the Tagus rose suddenly to 30 feet above their ordinary level, and retired immediately with such force, that the middle of the river was observed to be dry. Four minutes afterwards the same phenomenon recurred, and it was three times repeated. Shakings of the sea.

Similar motions occurred the same day at Madeira, at Guadaloupe, and at Martinique. In the earthquake which proved destructive to Lima in 1746, the ocean had a movement of the same nature; but, proportionate to the mass of water which was thrown into agitation, it rushed forwards upon the land for a space of several leagues. All the large vessels which were in the port of Callao were swallowed up: all the small craft were driven beyond the town. Navigators assure us, that ships are very often dreadfully tossed by a sudden and convulsive motion in the sea, very similar to those which shake the land. These agitations of the sea, perhaps take place, though there is no corresponding shaking of the earth. At other times they are the effect of submarine shocks in the very bottom of the ocean.

The causes of these catastrophes are not well ascertained. It appears that there are several concurring causes, of a very different nature. Some slight shocks arise, without doubt, from fallings in of the ground, and subter- Causes of earthquakes.

[1] Collect. Acad. vol. vi. Delamétherie, Theorie de la Terre, § 1057.

raneous sinkings, which take place after great droughts. At other times the shocks may be produced by the terrestrial and atmospherical electricity, which seeks to recover its equilibrium. These phenomena, the reality of which can scarcely be contested, depend upon the temporary constitution of the seasons. The most generally received opinion attributes earthquakes to *elastic vapours* enclosed in subterraneous cavities, whether they arise from the abundance of rain collected in the craters of volcanoes, or are disengaged from the inflammable substances with which the subterraneous rivers or waters of the sea may come in contact; or, finally, are extricated by the fermentation of that subterraneous fluid, which Deluc supposes to be the residue of the saltwaters of the globe. These vapours become diluted by heat, and in seeking an outlet they raise up or shake the earth [k].

If this last hypothesis be true, as many circumstances lead us to suppose, the Japanese have not been wrong in saying that it is a great submarine dragon which raises up the earth by its breathing. A similar tradition prevails in the mythology of the Scandinavians. It is probably in allusion to this, that Homer has given to Neptune the epithet of *Ennosigaios*, that is, he who shakes the earth.

The raising up of the earth.

We have not attempted to diminish the terror which earthquakes invariably inspire, but we must however contradict the framers of systems, who have exaggerated the effects with the view of exhibiting in them the sole cause of the revolutions which have happened on the surface of the globe. There is no example in the records of authentic history, of any land, or considerable island having been formed by a volcanic eruption, or by an earthquake; the most considerable heaving up, which is known, is that of the volcanic ground of *Jorullo*, in Mexico, which took place in 1759. For the space of half a square league, flames were observed issuing from the plain; fragments of burning rocks were thrown up to a prodigious height;

[k] Deluc, Lettres à Blumenbach, p. 164, 184. French edition

and through a thick cloud of cinders, streaked with volcanic fires, the spectators thought that they saw the softened crust of the earth swelling up. In the midst of the heaved up earth, which is about 500 feet in elevation, several thousands of little volcanic cones arise, sending forth their smoke, and occasioning a subterraneous noise. Amongst these small volcanoes six great ones rear their heads, to the height of about 1500 feet above the ancient level of the plain.

Strabo speaks of a piece of ground being raised up near Methone, in Greece, to the height of seven stadia, which, taking the stadium at 1111 to the degree, must have been more than 2200 feet. We are informed of a volcano of considerable elevation in the island of Timor, which sunk entirely down, leaving in its place nothing but a muddy marsh[l]. It follows from these and similar examples, that the ground which has been either elevated or swallowed up by the volcanic force, consists only of those masses of burning or scorified rocks, which form the chimneys of the volcano, and which, when projected from its mouth, almost immediately fall back around the orifice [m].

Even the phenomena of Jorullo accord with this theory. The thousands of little volcanic chimneys, which were forming at the same moment, presenting the appearance of a heaving up of the ground.

Of the new volcanic islands.

All that has been said as to islands having been created or swallowed up by volcanoes, is reduced then to the simple fact of the existence of submarine volcanoes, which sometimes elevate, and sometimes destroy the edges of their crater.

We shall elsewhere develope this general observation, when we come to trace the history of the island of Santoria [n], the best known example that there is of these kinds of revolution. We may safely conclude, that the islands actual-

[l] Humboldt, Essai sur la Mexique, 249—258. Beroldingen, Volcans anciens et modernes, I.

[m] Deluc, Traité élémentaire de géologie, §§ 210—214.

[n] See in a subsequent volume, the Description of Turkey in Europe.

ly created or destroyed by volcanoes can be only of very limited extent, and that the pretended catastrophes of Atlantis and Frislande, of which we have given the true explanation in another part of this work, cannot be ascribed to volcanic eruptions by men accustomed to examination before they believe.

Muddy eruptions.

Nearly allied to volcanic convulsions, are *eruptions of mud*, a phenomenon which, from time to time, takes place in volcanoes, but which occurs also independently of them, and as the effect of causes peculiar to itself. *Maccaluba*, in Sicily, is the most celebrated amongst the *terrivomous mountains*, to call them so. In its ordinary state, mud, half fluid, is observed to boil up in the craters, or funnels, which terminate each of the small protuberances raised up on this mountain, or rather upon this clayey hill. The mud rises in half globes, and falls down, after having emitted a bubble of air; but there are epochs when, after a great rain, all these small craters disappear, the whole mass of the mountain ferments, subterraneous thunders are heard, and a quantity of mud and stones spouts forth to the height of 200 feet. Not far from Boulogne, several quagmires, called the *Salses*, situated in rising grounds, composed of saline and alkaline earths, exhibit, on a small scale, similar phenomena, emitting occasionally smoke and flames[*]. The town and port of Tamar, in the Crimea, upon the border of the Black Sea, contain several hills, whence issue muddy eruptions. One of them has been seen to dart forth flames. In the Crimea also, and opposite the town of Temrak, an island was raised in the middle of the sea in 1799, which, after having cast forth mud, flames, and smoke, disappeared under the waves. Upon a tongue of land, opposite Taman, there was a hill, called in Tartar *Kouk-Obo*, which in 1794 experienced a terrible explosion. A column, of a pale red fire, shot up from it, to nearly 300 feet in height, and mud, mixed with bitumen, was projected to the dis-

The Salses.

[*] Dolomieu, Voyage aux Isles Lipari, in fine. Compare Spallanzani's Voyages, v. 223, 227, French translation.

tance of a quarter of a league [p]. The whole projected mass was computed to amount to 100,000 cubic feet; according to Pallas it consisted of a bluish clay.

The *Growing*, or *Increasing Mountains*, which are met with at the foot of Caucasus, near Bakow, and near the mouth of the river Kur, belong to the same class. They are produced by springs, which throw out a salt claggy mud; and in this manner hills above 400 feet high are formed [q]. Volcanoes themselves throw out, though with greater violence, substances dissolved in water. Those which crown the chain of the Andes, near the city of Quito, emit only a small portion of scoriæ, but an enormous quantity of water and clay, combined with carbon and sulphur [r]. These examples may suffice to show, that the eruption of earthy substances in watery solution, far from being an insulated and unimportant phenomenon, forms even to this day one of the most remarkable sources of the changes which have taken place on the surface of the globe; and that in former ages it probably had a very great influence in the formation of our mountains. We think we may ascribe, if not to the same, at least to a similar cause, the origin of the coagulated rocks known under the the name of *Basalt*.

Conclusion.

It is thus that all the elements of nature are armed for mutual destruction. What are those revolutions that we behold, in comparison of those which must have operated together in the creation of the world, and which perhaps are one day destined to accomplish its final destruction. May not those stars, those suns without number which guide the mariner in the midst of the pathless deep, be in a moment extinguished? May not this arch of the globe which supports us, give way beneath our feet? Is not the equilibrium of the seas liable to be subverted, and will not the foaming billows one day roll over these continents

[p] Pallas, Voyage dans la Russie méridionale.

[q] Leech, Voyages cités par Georgi, Description de la Russie, I. 114.

[r] Humboldt, Tableau des régions équatoreales, 130.

which are at present covered with the monuments of human industry? May not the earth approach too near to the sun, and be swallowed up by it like a drop in the ocean? May it not wander into those remote and dreary regions of space, where the solar heat is too feeble to support the principle of life? How frightful would it be to exist in the midst of these perfidious elements, in the bosom of this perishable universe, without the consoling thought of a supreme intelligence, that both checks and wields at will the formidable and blind powers of nature? It is only the belief in an order of things superior to matter, in a moral world, that can fortify us against the terrors by which our physical existence is every where assailed.

BOOK XIX.

Continuation of the Theory of Geography. View of Geological Systems, or Opinions regarding the Formation of the Globe.

In the course of this work, we have seen that the physical geographer cannot refrain from connecting together certain facts, which frequently recur, and deducing from them general conclusions. He is even forced sometimes to present facts in an hypothetical manner, because observers have furnished him with their remarks under that form. But physical geography affirms nothing which is not established by experience. Systems of geology, on the contrary, have for their professed object to trace the progress of unknown revolutions, by the assistance of monuments which are often equivocal.

The authors of such systems, in the absence of positive facts, do not scruple to call in the aid of analogy, and thus, by hypothesis after hypothesis, they analyze and recompound the vast globe of the earth, as if it were a piece of metal, which the chemist could fuse in his crucible.

We shall endeavour to prove, that this pretended science, or speculative geology, promises no certain results, since it oversteps the evidence of facts, that is, since it deviates from the sure and beaten paths of physical geography.

In the first place, the portion of the globe which is known to us, does not constitute, at the very utmost, the thousandth part of its entire mass. Our excavations do little more than scratch the surface of the earth; our geo

Insufficiency of geological observations.

logists have surveyed with attention scarcely the half of Europe, or the tenth part of America and Asia; the observations which have been made are extremely few; and yet unbounded scope has been given to speculation. We do not know whether the interior of the globe is composed of substances analagous to those occurring on its surface, or consists solely of a mass of sand; whether it contains within a central fire which continually burns, or a vast reservoir of primitive waters; or whether, finally, the globe is only a hollow sphere, filled with air and vapours. As to these matters, we know nothing whatever, and can by no arguments, astronomical or physical, prove either the truth or the falsity of any of these opinions. In the vast and unexplored recesses of the globe, it is possible that there may lie concealed, agents so active and so powerful, that to them the various revolutions which the earth has undergone, may have been the work only of so many moments.

As long as the interior of the globe remains unknown to us, the conclusion which we may draw from facts observed on the surface, can be no more than probable in reference to these facts; but whenever we attempt to combine the conclusions in order to form a general system, their uncertainty will clearly appear; for, opposite to a finite sum of probabilities, however strong we may suppose them, there shall arise an infinite sum of unknown terms, of which one alone may perhaps be sufficient to counterbalance all our probabilities.

Value of hypotheses in geology.

It is in vain to compare geological hypotheses with those made use of in astronomy, natural philosophy, and chemistry. The theory of attraction, for example, is purely and simply a mode of stating a fact furnished by observation; it is a formula for computing the known effects of certain unknown forces, as to the nature of which no opinion is expressed. But the authors of those philosophical poems, improperly called theories of the earth, will not confine themselves to the stating of facts; they have recourse to mere suppositions. But, what is more, even facts

in geology, however completely they have been established, cannot be expressed in mathematical terms; they are incapable of being subjected to calculation. We therefore apprehend that chemistry and physics, far from furnishing arms to extend the empire of geology, must, on the contrary, disavow the premature and too general application that has been made of some theoretical principles, of which philosophers and chemists have availed themselves only in questions of doubtful speculation. Philosophy may admit, without complete proof, the existence of a gravitating, a calorific, an electrical, a magnetic, and a galvanic fluid, when it distinctly perceives their effects in a number of carefully conducted experiments; but does it follow from this, that speculative geology, in the absence of such perceived effects, may lay hold of these principles which are still hypothetical, and make use of them as if they were agents perfectly known, and entirely subjected to its power? And if geologists have the candour to own that they know nothing whatever of the part which the different etherial or atmospherical fluids may have acted in the primitive formation of the earth, is not this the same as owning the absolute impossibility of their being able to form a primitive history of the globe? The theory of chemical affinities, or of atomic attractions, has furnished us with some just ideas concerning the primitive formation of solid detached bodies; but as long as the law according to which these attractions decrease, remains unknown, and whilst we neither know the agents nor the processes which nature employs in the greater number of cases, the chemist can impart to us no positive and precise information as to one single operation of the unknown power which has produced, or which sustains, the universe. Still less can he trace the immense chain of its operations, the last link of which is attached to the throne of the Almighty.

Abuse of physic and chemistry

The strongest argument against the possibility of a theory of the earth, appears to be suggested by a consideration of that admirable system of *celestial mechanics* whose unalterable laws maintain the globes in their respective posi-

Connection of geology with celestial mechanics.

tions and their mutual dependence. In this system of the universe, so completely established by astronomy, it is difficult to conceive a derangement of any part, which does not sensibly affect the whole. But speculative geology perceives nothing but derangements and convulsions. The changes in the situations of the poles, the augmentation and diminution of the magnitude of the earth, the immense volume of water which held all terrestrial substances in a state of solution, the processes of desiccation and refrigeration, and many other great revolutions which must be assumed in constructing a theory of the earth, could scarcely have taken place without altering the equilibrium established by universal gravitation. Besides, as all the globes of our solar system are evidently bodies subjected to uniform laws, theories of the earth must inevitably degenerate into cosmogonies. Every time that men of genius have engaged in speculations upon the history of our globe, they have found themselves forced to extend their hypotheses, so as to embrace the whole solar system; they have been gradually led on to the discussion of questions altogether beyond the limits of our faculties, such as those concerning the eternity of the world, and the essential properties of matter.

Such are the reasons which seem to us, *a priori*, to prove the impossibility of establishing any general theory regarding the primitive formation of the globe. Let us see whether a review of the various systems hitherto proposed by geologists, will lead us to a different conclusion.

Systems of geology.

Almost all geological opinions may be reduced to two great classes, the opinions held by the Vulcanists, and those entertained by the Neptunists.

The Vulcanists.

The Vulcanists tell us, that the earth at first was in a state of igneous fusion; that it then gradually cooled, and was covered with water only at a subsequent period. Air and caloric, or fire, were powers which gave to it its existing shape. The land was heaved up by an internal force; the irregularities which diversify its surface are the effects

of volcanic eruptions; and the transported soils have been formed by the disintegration of the higher grounds.

According to the Neptunists, the earth was originally in a state of aqueous and cold solution, at least to a certain depth. Solid bodies were formed by desiccation, precipitation, crystallization, &c. The primitive ocean has retired, or rather has disappeared, in consequence of the land giving way and sinking down from its own weight; the ternary soils have been formed in the bosom of the waters. The Neptunists.

These ideas, more or less extended, varied, and combined, constitute the basis of all the theories of the earth which the industry of Delametherie has been able to collect [a].

The Egyptians appear to have adopted the Neptunian system. According to them, the waters had covered the whole earth, but were now concealed in the vast cavities which were supposed to exist in the interior of the globe, and from which they were one day destined to issue forth. They maintained, that a great island or continent, called Atlantis, had sunk in the bosom of the sea. It is to Plato that we are indebted for these fragments of the Egyptian system [b]. Ideas of the Egyptians.

It appears that the Hebrews and the Chaldeans held the same opinions as the Egyptians, except that the Chaldeans believed in the existence of a central fluid similar to the atmosphere, and considered the globe as having been thrice covered with water—first by the chaotic waters, and then by an universal deluge. This deluge, according to the Chaldeans, was the effect of a change in the axis of the globe, occasioned by an irregular attraction of superior planets. The Hebrews represent it as the work of omnipotent power. Opinions of the Chaldees and Hebrews.

The most ancient writings of the Hebrews, attributed to their law-giver Moses, have also preserved a most interesting tradition, the vestiges of which are plainly to be traced Mosaic tradition.

[a] Delamétherie, Théorie de la Terre, tome v. p. 280-533.

[b] Plato, in Timæo, id. in Cratea. Manethon, Epit. Natur. Hecat. de Philos. Egypt. lib. 1.

amongst many other nations, namely, that of six geogonical epochs, or a successive formation of the globe. If the Hebrews speak of six days, and the Etruscans of six thousand years; if the Indians have extended these epochs to millions of years, this makes no real difference. These expressions, however contradictory they may seem, being only the varied phraseology in which the ancient poets and prophets so frequently indulge.

Deluc, whose faith in Christianity cannot be suspected, has never been able to explain the geogonical system of Moses, otherwise than by taking the word days in a figurative sense, for some indefinite period of time. Every theologian knows, that to explain the Hebrew prophets, and particularly Daniel, recourse must be had to a similar method of interpretation [c].

It is obvious, that these Neptunian systems have had their origin in *new countries*, which have been formed by the slow or sudden retreat of the sea, such as Egypt, Chaldea, and the borders of the Gulf of Arabia. As to the universal deluges which happened after the first drying of the globe, it is remarkable that they are generally represented as sudden, and of short duration. We cannot see how such revolutions could have taken place, without adopting the idea that the globe of the earth is internally hollow, and that the dry land sunk into it. Accordingly, the formation of the mountains, by the sinking in of the land, necessarily forms a part of all the geogonic systems which proceed upon the humid plan.

The volcanic system equally appears to have originated with some Oriental nations; for the Greeks, who embraced it, derived their information from the east. To this system belongs the hypothesis of the *raising up of the moun-*

[c] Compare Deluc, Lettres à Blumenbach, 1798. Id. A Treatise on Geology, 1809. Geogony, in 2 vols. (in German) by Silberschlag, Berlin, 1780, contains a very good explanation of the Mosaic system, regarded in a historical point of view. The celebrated Orientalist, Eichhorn, at Gottingen, has explained it poetically. See his Repertory of Biblical and Oriental Literature. vol. iv.

tains, to which some Hebrew prophets, posterior to Moses, appear to allude.

Vulcanists of Asia.

Belus, the Assyrian lawgiver, appears to have admitted that the earth exists periodically in a state of universal combustion, and in that of general inundation [d]. According to a passage of Trogus Pompeius [e], the two systems which attribute the origin of the world to fire and to water, divide the opinion of the philosphers of the east. Those who adopted the former, thought that the earth had slowly and successively cooled, from the poles to the equator; their antagonists maintained, that the sea had gradually retired.

Neptunian systems of the Greeks.

The ideas of the Orientalists furnish the Greeks with the foundation on which they have reared all their fanciful geogonic superstructures. Thales imported from Egypt the Neptunian system, which was probably that of all the ancient Greek poets and mythologists. Homer seems to adopt it [f].

From Aristotle and Plutarch we learn, that these ancient Neptunists founded their system on one single principle, humidity; because, from humidity, animals, plants, and even fire, appear to derive their origin [g]. Were not these ancient philosophers as far advanced in knowledge as our own modern geologists, who say, that a watery solution has alone been able to hold, in a dissolved state, all the solid, liquid, and fluid bodies, whose union composes the globe and its atmosphere?

The description which Lucretius, Virgil, and Ovid, give us, of the first formation of the terrestrial globe, contain all the principal ideas of the modern Neptunian theories; solution in a vast fluid, or in chaos, chemical precipitation by

[d] Berosus, ap Seneca, Quæst. Nat. iii. c. 29.

[e] Justin, Hist. Epit. lib. ii. cap. i. Cicero, De Nat. Deor., i. Quæst. Acad. iv. Sen. Quæst. nat. iii. 13.

[f] Iliad, xiv. 246.

[g] Aristotle, Metaphys. lib. i. cap. 3. Comp. id. Météorol. i. 14. Plut. de placitis Philosophorum, b. i. c. 3.

attraction or affinity, mechanical precipitation and deposition, and, at last, coagulation and consolidation.

Whether there have been any pure Vulcanists in Greece.

The number of Grecian philosophers who attribute the origin of the earth exclusively to elementary fire, does not seem to have been considerable; for we cannot affirm that such was the opinion of Pythagoras, although he looked upon the soul of all beings as a particle of divine fire. The obscure Heraclitus was the first who said, that "fire had formed all things, and could destroy all[h]. The stoics, according to Cicero, should have been of this opinion, but Seneca declares, on the contrary, that they regarded water as the principle of the world. Besides, when Heraclitus said, "that the earth was the thickest sediment of fire, that water was earth dissolved by fire, and that water in the state of vapour formed air[i]," it is evident that he did not think of the system of the Vulcanists; he intended only to found a general system of corpuscular philosophy.

Philosophy of atoms.

The same remark holds with respect to those who ascribed the creation of the earth and the universe to the concourse of particles or atoms scattered in the immensity of space. In the atoms of Democritus and Epicurus, which adhered to one another by means of some small inequalities of shapes, which served as a kind of crotchets or hooks, in the *corpuscles which prefer* and attract each other, in virtue of their similar nature[k], we recognize the fundamental principles of our theory of chemical affinities, and, consequently, of our most modern and most celebrated systems of geology. The union of atoms is evidently the same thing as the *simple attraction* of particles; and whether we say these corpuscles chuse to *unite, because they are* of a similar nature, or these particles tend to unite by an *elective attraction*, all the difference consists only in the greater or less precision of the expressions.

[h] Dio Laert. lib. ix. S. Justin. Parœnet. ad Græcos. Stob. Physic. Eclog. i. c. 13.

[i] Plut. de Placit. Philosoph. i.

[k] Paresque cum paribus jungi res, &c. Lucret.

The idea of Franklin, who makes every thing to originate from air, had been broached by Anaximenes of Miletus, whose opinions are without doubt misrepresented by the contracted minds of those who accuse him of atheism[l]. The Greeks did not rest satisfied with these general systems; they formed hypotheses of a more definite character, founded upon facts supplied by the physical geography of the countries then known. The flowing out of the lakes or marshy pools which covered Thessaly before the formation, or rather before the enlargement, of the valley of Tempe[m], suggested the idea, that all the inland seas, and specially the Pontus-Euxinus, or Black Sea, had been originally inclosed lakes, to which some violent revolution had opened an outlet. Xanthus and Strato having observed that the soil of Upper Asia contained sea shells, justly concluded that these countries had been covered with sea water[n]; but when Strato attempts to explain this phenomenon, which is common to all the globe, by supposing a local cause, by the existence of an ancient inland sea, formed by the union of the Pontus Euxinus with the Caspian, he falls into one of those paralogisms which appear to be almost hereditary in the pretended science of geology. We shall prove, in the proper place, that such an inland sea has not existed since the commencement of historical times. The general revolutions which may have been caused by the breaking up of the great lakes and interior seas, must have taken place long before the existence of the human race; and the deluges that have been occasioned by a derangement of the sea, belong to an age far beyond the reach of history. This is completely proved by the occurrence of animal remains[o]. But the soil of Greece, from its very nature, must have frequently given way and sunk

System of Anaximenes.

[l] Plut. de Placit. Stob. i. c. August. de Civ. Dei, viii. 2. Cic. de Nat. Deor. i.

[m] Herod. vii. 129, 130. Strab. ix. 667. Almel. Lucan. vi. 364, &c

[n] Strab. Geog. i. 35. Alm.

[o] See above, Book XII. near the end.

down, and consequently the country must have frequently experienced local inundations. The deluge of Deucalion desolated Thessaly, especially the mountainous canton named Hellas[p]; that of Ogyges overwhelmed Bœotia[q]. Popular tradition naturally referred to those disasters which had ravaged whole provinces, every ancient inundation, the remembrance of which was preserved in any district. Thus a single opening, of inconsiderable extent, was shewn in Attica as the *funnel* by which all the waters of Deucalion's flood were drained away[r]. Twelve or fifteen centuries after the epoch assigned to these events, historians began to collect these scattered traditions, and to compose from them highly finished descriptions of pretended universal deluges, unknown to more ancient authors[s]. Other Greek writers, dissatisfied with these sudden revolutions, these eruptions and deluges, invented the hypothesis of the gradual drying up of the sea. Aristotle charged them with drawing a false conclusion from authentic facts. "It is true," said that great naturalist, "that several countries, formerly covered with water, are now reunited to the mainland, but the contrary also happens; the sea has made several eruptions[t]. The hypothesis of alluvial additions to the land was also proposed. Polybius imagined that the Pontus Euxinus, or Black Sea, would be filled up by the mud which the rivers conveyed into it[u]; but two thousand years have been insufficient to fulfil this geological prediction. The waters of the river Pyramus, in Cilicia, have made no addition to the opposite shores of Cyprus, as the oracle had foretold. Lastly, some of the Greek philosophers attributed to volcanic eruptions effects much more considerable than those for which we have any historical evidence.

Deluge of Deucalion and Ogyges.

Hypothesis upon the drying up of the sea.

p Apollod. i. c. 7. Arist. Meteorol. i. 14.

q Varro, de R. R. iii. comp. Fréret. Mémoire sur les Déluges d'Ogyges et de Deucalion. Académie des Inscriptions, t. xxiii. p. 129.

r Pausan. i. cap. 18.

s Diod. v. 19. Lucian, de Dea Syria. Plut. de Solert. anim.

t Arist. loc. cit.

u Polyb. Hist. l. iv. cap. 10, 42. Edit. Gronov. i. p. 128, 434.

Strabo imagined that they could raise and swallow up whole countries; and he mentions, as a proof, two towns in the Peloponnesus that were overwhelmed by an earthquake [x]. Thus do we discover, among the ancient Greeks, the germ of all the theories of modern geology, and the same disposition to confound facts belonging to different epochs, to exaggerate phenomena, and to deduce general conclusions from local facts.

Ideas of Palissy, 1581.

Amongst the moderns, *Palissy* was the first to unfold correct ideas respecting fossil shells; he protested against the misconceptions of those who were for considering them only as the sportive productions of nature; he even ventured to maintain, that these fossil remains of marine animals were too abundant to have been carried into the places where they are found, by a sudden catastrophe resembling the deluge described by Moses [y]. *Stenon* demonstrated anew these truths, which were of too bold a character for the age of Palissy. Proceeding still farther, he acknowledged that the strata of the earth must have been formed as deposits in a fluid, and that mountains owe their origin to the subsiding and rupture of strata originally horizontal [z].

Ideas of Stenon, 1669.

System of Burnet, 1681.

Burnet, a man of great talents, but who had not carefully observed phenomena, constructed the first complete theory. Before the deluge, says he [a], the surface of the earth was a level plain, with neither mountains nor valleys. All substances were disposed around the centre of the globe, according to their specific gravity, the water everywhere occupying the surface. The oily substances, however, being lighter than water, formed by degrees an upper layer, which enveloped the waters and the whole of the globe. Upon this extremely fertile crust, the antediluvian generations lived in perpetual spring. The deluge made

[x] Strab. i. 54, edit. de 1620.

[y] Encyclopédie Méthod. Géographie-Physique, i. art. Palissy. Stenon, Dissert. de Solido, intra solidum.

[z] Theoria telluris sacra, &c. London, 1681.

every thing change its appearance; the crust became dry, and the accumulated waters struggled against this light covering; it burst and sunk into the abyss of waters. This changed the axis of the globe, and consequently the temperature of its climates. The edges of the crust, set up again in several places, formed our present mountains. It is unnecessary to shew, that this system, founded solely upon the observation of floating islands, is altogether insufficient to explain the origin of those hard and heavy rocks of which our mountains are composed.

Descartes, 1670.

Descartes[b] and Leibnitz[c] take a still bolder flight, imagining that the earth is a small sun, covered with an opake crust, which, by sinking down, gave birth to the mountains.

Leibnitz, 1683.

Leibnitz considered the whole mass of the globe as having been vitrified; an idea quite untenable, although Buffon has been carried away with it.

System of Whiston, 1708.

Another arbitrary theory was proposed by Whiston[d]. This astronomer considers the earth as a comet, which has forsaken its original tract, from a cause which he does not specify, to revolve in the orbit of a planet. Being no longer subject to the extremes of heat and of cold, the chaotic matter of this ex-comet was precipitated according to the laws of specific gravity. A part of the primitive heat of the comet was preserved in its centre; this centre was surrounded by water, the exterior crust of the globe was of uncommon fertility, and the inhabitants lived for centuries. But the excessive warmth had the effect of inflaming their blood; they became so impious, that the Creator was compelled to destroy them with a flood. For this purpose he caused another comet to approach, which enveloped the earth in its immense tail; and as the tail of a comet is composed of vapours and water, (who dares to doubt it?) the temperature of the earth was considerably diminished. Besides, the attraction of the comet disturbed the equilibrium

[b] Principes de Philosophie, Part iv. No. 2.

[c] Protogæ, in act. erud. 1683.

[d] A New Theory of the Earth. Lond. 1708.

of the waters in the interior, and thus occasioned a violent flux and reflux in their mass. The exterior crust of the earth being violently shaken, sunk down in one place, and cracked in another. In this way, an universal deluge took place. The comet, after executing the will of the Creator, receded; the waters, recovering their equilibrium, entered again into the subterraneous cavities, which had been sufficiently enlarged to receive the waters of the comet. The coldness, and other bad qualities of these waters, have reduced the earth to that degree of barrenness and exhaustion which we now so much deplore. This hypothesis of Whiston has often been revived in whole or in part. Dolomieu has borrowed from it his principal ideas.

System of Woodward, 1708.

Woodward, a countryman of Whiston's, and an indefatigable and scrupulous observer, invented a much more modest theory [e]. He admits, that all terrestrial substances have been in a state of aqueous fluidity, and supposes that the whole interior of the globe contains an abyss of water which must have been sufficient for the purpose. The deluge of Moses consisted in a falling down of the crust of the globe into this great abyss, the waters of which, according to Woodward, possessed a peculiar dissolving power, which did not act upon shells and other remains of the animal kingdom. It is evident that the acuteness of Woodward led him to perceive the impossibility of explaining the position of so many beds of shells in the midst of stony masses by the occurrence of a single short-lived inundation. But his *dissolving power* is, according to his own admission, an occult and miraculous property. An intelligent German, Camerarius, in attacking Woodward, conjectures, what has since been demonstrated, that banks of shells neither have nor could have been transported by any deluge; and that, on the contrary, the animals to which the shells belong have lived and died in the same place [f]. In replying to Camerarius, who states his opinion in a manner far from distinct,

[e] Woodward's Essay on the Natural History of the Earth, 1723.

[f] Camerarius, in Dissert. Taurinens, p. 226, Tubing, 1712.

Woodward asserts the fact that volcanic eruptions have given origin to no considerable mountain, far less to islands and entire countries [g].

Tournefort, 1700. We shall say nothing of the vegetation of stones, the dream of the celebrated Tournefort, nor of some detached

Scheuchzer, 1700. propositions of Scheuchzer, whose genius was fettered by the prejudices which attributed all the changes of the globe

Fontenelle, 1716. to a single deluge. The ingenious Fontenelle was the first who had the merit to assert that more revolutions than one must have contributed to model the surface of the globe, and to heap up those vast ruins which surround us on all sides.

The volcanic system found at this same period several warm and able defenders, whom it would be wrong to pass

Ideas of Ray, 1693. over in silence. Ray imagined, that at the very moment of the creation, at the time of the separation of the humid and solid substances, there were earthquakes which heaved up the mountains. The earth gradually emerged from the waters of the sea, which gave to the marine animals time to retire into the bosom of the ocean [h].

Hook. 1705. Hook, while he supposed that strata were originally formed like sediment in a fluid, admitted the occurrence of volcanic eruptions sufficiently powerful to raise up extensive

Lazaro Moro, 1740. tracts of ground, and even to melt and calcine them [i]. Lazaro Moro, observing that there are some mountains which contain neither the remains of sea animals, nor any marks of stratification [k], attributed a volcanic origin to all the secondary mountains; these are, in his opinion, flowings of lava which have had their origin under the waters. By mo-

System of Raspe, difying and combining these different ideas, Raspe composed his volcanic theory of the formation of new islands, a theory which many distinguished vulcanists have inaccurately copied [l].

[g] Natural History of the Earth, Enlarged and Defended, &c. p. 115. sqq. Lond. 1726.

[h] Ray, Three physico-theological Discourses, p. 164, Lond. 1693. 3d edit.

[i] Hookii, Oper. Posthum. 299, 310. Edit. Lond. 1705. in folio.

[k] Laz. Moro, de l'Orig. des coquillages fossiles, ch. 12, 13. 1740.

[l] Raspe, Specimen historiæ naturalis globi terraquei præcipuè de novis e mari natis insulis. Leipzick, 1763.

These different systems were completely eclipsed by that which was created by Buffon, and which his splendid genius adorned with all the charms of poetry. According to him, the suns and comets were formed as we see them, and projected with an impetus sufficient to carry them forward in their orbits. But about 96,000 years ago a comet fell obliquely into the sun, and detached from it the 650th part. This entire mass, hurled into the immensity of space, separated into fragments, which formed several planets of our solar system, and which, from their rotatory motion, acquired a spherical shape. Our globe was in a state of incandescence, but its surface by degrees cooled and consolidated, retaining however many immense cavities. Part of the vapours, which were elevated in the atmosphere, condensed and formed the seas. These waters, acting upon the solid part of the globe, decomposed a portion of it, and in this way formed the land and stones. The waters of the ocean, attracted towards the equator by the tides, brought with them a vast quantity of dissolved substances, "and then," says Buffon, "gave rise to those great chains of mountains which extend from east to west. Unfortunately these chains do not exist; the great range of mountains which surrounds the globe has another direction [m]; so that Buffon is to blame for explaining, by a supposition improbable in itself, a fact which is quite imaginary. But let us proceed with the statement of his theory. The primitive waters of the globe withdrew into the cavities of which we have already spoken, then the continents appeared. The earth, in the space of 43,000 years, grew so much cooled that its surface could admit of the existence of vegetables and animals, which started first into being about the pole, and gradually spread themselves towards the equatorial regions. The secondary strata were formed from the decomposition of vitrified substances, mixed with marine sediment; accessory causes, such as winds, currents of water, volcanic eruptions, and earthquakes, afterwards modelled the moun

System of Buffon, 1745.

[m] See Book vii.

tains and the valleys. The ocean slowly changes its shores by its general motion acting against the eastern coast, which it imperceptibly destroys, and in this manner may have several times completed the tour of the globe [n].

The system of Buffon, refuted in its principal points by the observations of naturalists, is no longer supported even by those who consider fire to have been the chief agent in the formation of the globe. All hypotheses which pretend to explain the first origin of our globe, and the manner in which it was projected into space, are now regarded as chimerical. Geology attempts only to ascend by the examination of physical monuments from one epoch to another, until it arrives at a state of things anterior to all these monuments [o]. At the same time, the rapid accumulation of facts has led the most enlightened men of all parties not to exclude any particular cause [p],—a principle which has, in part, produced a blending of different systems, and a mutual tolerance for moderate opinions.

Theory of Deluc, 1770-1810.

The theory which is now most keenly supported, is that of Deluc. This philosopher supposes that the earth, and all the celestial bodies, were masses of confused elements, in which the divine will, by communicating to them a certain quantity of light, produced chemical precipitations, whence was formed the crust of those solid rocks whose fragments we see around us. This consolidated crust sunk down several times; the remaining edges, supported upon the partitions of subterraneous caverns, formed the mountains. The waters which at first covered the whole globe, filtered down into the central parts, where the ancient chaos always subsisted; then appeared the first continents, of greater extent than ours, but suspended above immense caverns; and, before they were enlightened by the sun, producing vegetables of a nature different from ours; the remains of which form our coal mines. The present continents, con-

[n] Buffon, Theory of the Earth, in the 1st vol. of his Natural History.
[o] Deluc, Elemens de Geologie, § 10, p. 11.
[p] Delamétherie, Théorie de la Terre, § 1700.

cealed under the sea, were covered with deposits of shells; volcanic eruptions spread their beds of lava. By a general and final subsiding, the primitive continents sunk into the recesses of the subterranean cavities. The sea was precipitated upon the land, and engulphed the whole race of the inhabitants. This catastrophe was the *universal deluge*, described by Moses, the traces of which are to be found amongst almost all nations. It was then that our present continents, formed beneath the ocean, suddenly arose into view. In the light lands of these continents were found, buried in promiscuous heaps, the remains of quadrupeds once the inhabitants of islands which had sunk down before the universal deluge, and the skeletons of cetaceous animals which had peopled the sea. The preservation of these remains, which are still met with almost entire in cold countries, and the inconsiderable thickness of the beds of the vegetable mould formed above our continents, unite to prove that their antiquity, or rather their appearance above the waters, is not to be dated many ages beyond our own [q].

Explanation of the universal deluge.

Such is the theory of the celebrated naturalist of Geneva. The principal feature of this system, viz. the repeated subsidings supposed to have taken place in the surface of the globe, and some of its subordinate details, particularly those regarding the origin of animal remains, have obtained for it a very favourable reception among philosophers. There is some difficulty in conceiving the existence of the vast cavities in which the antediluvian world was engulphed; it would seem that this idea, borrowed from Woodward, has been introduced into the theory, solely from a desire of accounting for the deluge.

Some naturalists, who admit, with Deluc, that the earth was formed in a state of aqueous fluidity, differ concerning the rank they assign to the agents which have produced the revolutions and ruptures of the crust of the globe. Saussure sometimes expresses himself, as if he ad-

[q] Deluc, Lettres sur l' Histoire de la Terre, addressées à M. Blumenbach, id. Elémens de Géologie.

mitted heavings up of the earth by volcanic fire, " or by other elastic fluids," in order to explain how beds of granite, which serve as a base to all the others, have, in certain places, been so elevated as to form the summits of mountains [r]. But the idea which he has uniformly maintained, is, that of very violent currents, which, by agitating the ancient sea, drew along with them, to a great distance, the fragments of primitive rocks, particularly of granite, which are found scattered on the surface of ground of secondary, and even of ternary formation [s]. It is difficult to conceive currents possessed of a force capable of rolling to a distance, entire portions of mountains, even though we should suppose the valleys filled up, and forming an inclined plane. It is more natural to attribute the phenomenon in question to marine ice, which may have carried these fragments of mountains across the ancient sea.

Ideas of Werner, 1791.

The celebrated Werner, while he attributes a great influence to the subsidings, thinks, however, that various facts, and, amongst others, the position of basalt, are explained only by supposing a periodical increase and diminution of the mass of fluid elements.

Ideas of Pallas, 1791.

When Pallas explains the occurrence of the remains of elephants in Siberia, by imagining a general overflow of the waters of the Indian Ocean, which, according to him, would have covered and traversed the upland plain of Central Asia, as they rolled from south-east to north-west, he has recourse to earthquakes and volcanic eruptions, to produce so extraordinary and inconceivable a movement [t].

Theory of Delametherie, 1798.

The ingenious Delametherie has composed a theory very circumstantial in its details, and supported by many facts, in which he endeavours to reduce the revolutions of the globe to chemical laws, without, however, excluding the agency of mechanical causes. This chemist represents both the mountains and the valleys as having been formed

[r] Saussure, Voyage dans les Alpes, § 919.

[s] Id. Ibid. §§ 587, 1596, &c.

[t] Pallas, Observations upon the Origin of Mountain , p. 74. French Transl.

by crystallization in an immense fluid, which he gets rid of by means of evaporation, because he is determined to consider the central mass of the globe as a solid crystal.

Conjectures of Dolomieu, 1794-1800.

The opinion of Deluc, as to the comparatively recent date of our continents, has been adopted by a distinguished naturalist, who, without constructing any general system, has thrown out some detached views, which, however, are very fruitful in results. Dolomieu, it would appear, scarcely aimed at any thing more than to disencumber Whiston's theory of some of its hypotheses. All the geological agents of this philosopher; the solution of all terrestrial substances in a solvent which has been destroyed; the coagulation of these substances, which after the destruction of the primitive solvent were precipitated and crystallized, so as to form a crust; *the exterior cause, whatever it might be*, which breaks and pulverises this crust, and the tides of eighteen hundred toises in elevation, which set in motion the whole mass of waters, swept the bottom of the seas, raised and transported banks of shells, hollowed out the valleys, and modelled all the secondary ground;—all these agents, we say, exist already in the theory of Whiston. It is even difficult to imagine the possibility of all these violent and sudden revolutions, without the concurrence of some celestial body; but as every thing proves the stability of the planetary system, it is only to the comets that we can have recourse. But how is it to be proved, that these comets are bodies sufficiently dense to exercise such force of attraction upon the terrestrial globe? Tycho, Galileo, Kepler, Lahire, and Herschel, have regarded the comets as ethereal meteors. Thus theories of the earth invariably terminate in questions which admit of no solution; and all that we learn from studying them, is to distrust them.

System of Hutton Playfair.

"To distrust them!" some Scotsmen will exclaim, as they read these lines: "No; there is no more room for doubt, since Hutton and Playfair have discovered the true constitution of our globe. Do you not know that the present continents are wasting away by the action of the air, of gravitation and of flowing waters; that their materials, conveyed to

the coasts, are thence scattered by the different movements of the ocean over the whole extent of its bottom; that a great *internal heat* hardens these materials, whence is formed a mass like that of the mineral beds of which our continents are composed; that when this slow disintegration has destroyed our continents, the *internal heat* raises entire the beds formed at the bottom of the sea, in consequence of which its waters are spread over the wasted and demolished continents, and new continents are produced, to be subjected in their turn to similar disintegration? This great process of the alternate production and dissolution of continents, has already been frequently repeated, and no limit can possibly be fixed to its future duration [u]."

Our readers will of themselves perceive how very contrary this new system is to the evidence of facts. We shall only beg of them to observe, that the idea of the formation of mineral beds, by a subterraneous process similar to that which Sir James Hall has exemplified in his celebrated experiments, deserves to be thoroughly investigated, independently of its connection with the Huttonian system.

Whilst the philosophers of Europe were discussing the claims of these theories, the new world produced, or rather revived a system completely different from all of them. Franklin, like Anaximenes of old, supposed that not only all terrestrial substances, but even all matter, had existed as an elastic aeriform gas, irregularly diffused throughout the celestial spaces. Gravitation began to be felt; the gaseous particles were attracted towards various centres, and formed globes of air. This being supposed, it is easy to form a conception of the whole of Franklin's system. All substances are capable of being reduced to the aeriform state, therefore, concluded Franklin, they may all have been produced from the condensation of air, and thus must have been formed the exterior crust of the

Hypothesis of Franklin.

[u] Playfair's Illustrations of the Huttonian theory of the earth. Edinburgh, 1802.

globe, which in this system is merely a thin solid covering around a vast elastic fluid. The movements of this *central* air occasion earthquakes. This system, in short, is not a mere satire upon the theories of the earth, as some have supposed, it is an hypothesis quite as rational and ingenious as those of the geologists.

After having traced geology to the ethereal regions, what have we farther to do? Shall we augment the number of systems, by endeavouring to shew that the earth was once surrounded by a ring like Saturn, and that the falling in of this celestial vault gave rise to that chain of mountains [x] which occupies the ridges of the great continents, and thus forms, as it were, a belt to the globe? New hypothesis.

[x] See Book vii. p. 177. of this work.

BOOK XX.

Continuation of the Theory of Geography. Of the Earth, considered as the residence of organic beings.

SECTION I.

OF THE GEOGRAPHICAL DISTRIBUTION OF VEGETABLES.

We have decomposed the terrestrial globe into its solid, liquid, and aeriform parts. Let us now proceed to the consideration of those innumerable beings which exhibit the spectacle of life upon every point of the globe; which embellish its surface, which feed upon its inexhaustible stores of nutricious juices, and which, by one common destiny, find in it a thousand different graves. These productions, and these inhabitants of the earth, are not scattered over it by the hand of blind chance; general laws have assigned to each class of these organic beings its cradle and its grave; and these laws it becomes us to study before we commence the description of the different parts of the world.

Vegetables, from the abundance in which they are produced, and from their intimate connection with the soil, claim the first rank. It is for the botanist to examine in detail the treasures of the vegetable kingdom; the business of the physical geographer is only to mark its general arrangements; and here he finds abundant reason to admire that wisdom which presides over the constitution of the globe [a].

[a] Humboldt, Essai sur la Géographie des Plantes, Stromayer, Specimen Geographiæ botanicæ. Gottingæ, 1804. Bergmann, Geograph. Phys. Sect. vi.

The temperature of the air appears to form the only physical limits to the extension of vegetable nature. The scale of atmospherical heat serves accordingly as the ordinary scale for the progress of vegetation. Hence, under the burning climate of the torrid zone, we have only to ascend the mountains to enjoy the fruits and flowers of the temperate regions. Tournefort found, at the base of Mount Ararat, the common vegetables of Armenia; half way up, those of Italy and France; and, upon the summit, those of Scandinavia. Forster saw several alpine plants upon the mountains of Terra del Fuego [b]. If the valleys of the Andes are adorned with bananas and palm trees, the more elevated regions of that chain support oaks, firs, barberries, and a number of kinds common to the north of Europe [c]. Man, availing himself of this circumstance, has transported and disseminated almost over the whole surface of the globe, those herbaceous plants which supply him with his principal nourishment. Some useful plants have been rendered common to every climate by nature herself. Antiscorbutic vegetables, so salutary for the mariner, when languishing from the long use of salt provisions, are met with wherever there is a vestige of life. Cresses, succory, and wild sorrel, are found upon the ever-frozen banks of Hudson's Bay, and in Siberia, as well as in those blissful islands which are scattered in the midst of the Pacific ocean [d]. The shrubs which produce berries, and small fruits agreeable to the taste, thrive in the more inhabited countries. Even in Greenland, the currant bushes bear very good fruit. Lapland possesses a considerable resource in its shrubs, such as the barberry, the dwarf mulberry tree, the wild wood vine, (*vitis idæca*) and others. Neither external cold, nor the absence of the light, entirely extinguishes vegetable life. Caverns and mines give birth to a certain number of plants, particularly to those of the

Influence of temperature upon vegetables.

To what point plants support cold

[b] Bemerkungen, p. 154. (in German.)

[c] Humboldt, Essai sur la Geog. des Plantes, p. 34.

[d] Anderson, Cook's Third Voyage, passim.

cryptogameous class [e]. Several of the saxifragæ and ranunculus, the dwarf willows, as well as all the lichens, like the cold. The snow, far from impeding the vital functions of these vegetables, secures them against the effect of frosts, and furnishes them in abundance with the oxygen which it contains, and which, by increasing the vigour, accelerates the germination of the seeds [f].

Ramond has proved, that plants covered by the snow for several years, have yet continued to live beneath it [g]. The organization of alpine or polar plants, admits of a growth and development so rapid, that a few warm days are sufficient to fructify them [h]. Perhaps even perpetual snow may be the abode of a species of vegetation; at least Saussure has discovered in it a kind of reddish dust, very probably of a vegetable nature. Patrin, and Sokoloff, saw in Daouria, ground covered with vegetables, though entirely surrounded by perpetual snow [i].

Plants which grow in hot waters.

Extreme heat checks still less the productive energies of nature in the vegetable kingdom, provided that it be attended with humidity. We see plants grow not only upon the borders of hot springs, but even in the bosom of those waters which seem likely to destroy them. Examples of this kind are to be found from Iceland to the Cape of Good Hope, and from Kamstchatka to the island of Amboyna [k]. The sulphurous exhalations, and the foul air of volcanic caverns, seem to exert upon vegetation only a slow and limited influence, while to animals they prove instantly fatal [l].

[e] Scopoli, Diss. ad Scient. Natur. part i. p. 84—120. Humboldt, Floræ Friberg. subterr. &c.

[f] Hassenfratz, Journal de l'Ecole Polytechnique, 4e cahier, an. IV. p. 570—576.

[g] Ramond, Observat. p. 51.

[h] Martens, Voyage to Spitzbergen, p. 64. (in German.) Linnæi, Flor. Lapp. præf. pl. xx.

[i] Patrin, Voyage, p. 19.

[k] Olafsen et Povelsen, Travels in Iceland, (in German) ii. p. 31, and 181. Krascheninikow, Kamstchatka, (in German) p. 91. Sparman, Voyage, (in German,) p. 142. Labillardiere, tom. i. p. 324.

[l] Soulavie, Works of Hamilton p. 246. Smith's Tour, &c. ii. p. 103.

The most formidable obstacles to vegetation is the absence of humidity. Look to those sandy deserts under the equator, as well as towards the Pole, condemned to perpetual sterility. Not a drop of rain can settle on such a loose soil, always moving with the winds: Not a seed can strike root into it. It is unquestionably to causes very similar that we must ascribe the nakedness of several mountains; precipitous sides, or flat summits, afford no shelter to the vegetable colonies which the winds transport to them, whilst on other mountains under a colder temperature several plants are still supported. For example, the shivering mountain in Derbyshire produces no herbs, because its sides are daily decomposed in their schistous plates, which are constantly gliding down to the bottom [m]. The pressure of the atmosphere exercises a striking influence upon the configuration and life of plants. In vegetables the functions essential to life are performed chiefly at the surface; hence their great dependence on the medium by which they are surrounded. Animals are affected rather by internal excitement, and acquire of themselves the temperature which suits them. Respiration by the epidermis is the most important vital function of plants; and this function, in so far as it is subservient to the evaporation and secretion of fluids, depends on the pressure of the atmosphere; on this account the Alpine plants are so aromatic, so downy, and so plentifully furnished with secretory vessels. On the contrary, these plants grow with difficulty in the plains, where their respiration by the epidermis is impeded by the increased pressure of the air. [n]

Moisture necessary to vegetables.

Pressure of the atmosphere.

The chemical nature of the soil manifests its influence upon vegetables, rather by modifying their juices, their fruits, and the stateliness of their appearance, than by setting limits to their cultivation. Common salt, however, dissolved and scattered over the soil in considerable quan-

Chemical nature of the soil.

[m] Kuttner, Beytrage, &c. that is, Mém. sur l'Angleterre, cah. vii. p. 20.

[n] Humboldt, Tableaux de la Nature, ii. p. 115. n. 14.

tities, almost entirely prevents the growth of vegetables [o]. The fusion which lava undergoes, is probably the only cause which, for some centuries, has retarded the progress of vegetation on its surface, whilst the volcanic cinders raise most abundant crops [p]. In general, the soil serves only as a support and shelter to plants; they derive their nourishment from the water and the oily fluids which are collected together in the earth, and imbibed by their roots. A very small quantity of earth, dissolved in these fluids, is absorbed by the plant. Other causes also contribute to the support of vegetable life. Plants respire through their air-vessels the different fluids of the atmosphere; the presence of light especially is indispensable to the chemical operation, by which the pabulum or food of the plant is assimilated into its substance. The elementary earths obtained from plants by chemical analysis, appear rather to be the product and remains of the digestion by which the vegetable assimilates its food, than particles immediately derived from the surrounding soil [q]. The experiments of M. Schrader have shown, that the plants which vegetate in sublimed sulphur, give, when analysed, the same earth as those which grow in the ordinary way [r]. These observations, furnished by vegetable physiology, may explain why the siliceous earth forms so large a portion of the substance of plants, although the calcareous soils are generally covered with a more vigorous and more abundant vegetation than the granitic soils. The calcareous earth attracts humidity, diffuses warmth, and supplies the plants with fixed air; but it is the silex which predominates in the best vegetable earth [s]. The siliceous matter abounds also in grasses, and in several varieties of rushes. There have been found in the ashes of rye straw no less than 70 parts of silex in 100 of

Lands which abound in plants.

[o] Forskal, Flor. Egypt. p. 45.

[p] Hamilton's Works, p. 33. Brydone's Tour, vol. i. p. 116.

[q] Senebier, Encyl. Method. Veget. Physiol. vol. i.

[r] Schrader, deux Mémoires couronnés sur la nature des parties terreuses des plantes, Berlin, 1800. (in Germ.)

[s] Experiences de Fourcroy de Giobert, &c. Encycl. Nat. Physiol. Veget. vol. i. p. 276.

straw. The joints of the bamboo contain crystallizations of pure silex[t]. There are, however, other plants which are as much impregnated with calcareous earth, such as the *Charavulgaris*, the *Hypnum crista castrensis*, the *Neckera dendroides*, and several cryptogamic plants[u]. Other plants, such as the *Salsola kali*, the salicornia, the mesembry-anthemum, float almost in a solution of alkali. All the substances which chemistry procures from vegetables are reducible into four elements, namely, oxygen, hydrogen, azote, and carbon. The alkali which is extracted from several vegetables, probably owes its origin to the azote. Tannin, the principle of astringency which is found in the bark, the roots, and the leaves of some trees, seems to be carbon in a particular state. Vegetable physiology is full of uncertainty, and can furnish the geography of plants only with a very limited number of principles.

Extent of vegetation.

The empire of vegetation embraces the globe from pole to pole, and from the summit of the Andes, where the lichen creeps over the hardest rocks, to the bosom of the ocean, from which floating fields of algæ and fuci rise unseen. Cold and heat, light and shade, fertile lands and pathless deserts, every place and every temperature has its own kind of vegetation, which thrives and prospers there[x]. Plants of the cryptogamic class even ramify upon the dark vaults of mines, and upon the walls of the deepest caverns.

Progress of vegetation.

The course which vegetation pursues in its conquests over inorganic matter, presents remarkable gradations. "Let a volcano," says M. Humboldt, "raise up from the bottom of the sea, all at once above the boiling waves, a rock covered with scoria; or, to refer to a less dreadful phenomenon, suppose the nereides, with united industry, continue to elevate their cellular abodes for thousands of years, till, finding themselves above the level of the sea, they die, after having in this way formed a flattened isle of coral; organic force

[t] Lampadius, Samlung praktischer Abhandl., iii., p. 187. Davy, Nicholson, vol. ii. No. 27. p. 56. Macie and Russel, Philosoph. Transact. vol. lxxx. and lxxxi.

[u] Humboldt, Aphorism, p. 105, 106.

[x] Linnæus, Amœnitat. acad. vol. iv. p. 64.

is instantly ready to produce vegetation upon this rock: yet who can have brought there so suddenly the seeds of plants? Is it the birds, or the winds, or the waves of the sea? It is the great distance from the coasts which renders it difficult to decide this question. But scarcely has the air come in contact with the naked rock, when in the northern climates there is formed upon its surface a network of tufted threads, which appear to the unassisted eye like coloured spots. Some of them are bordered by lines bending outwards, sometimes single, sometimes double; others are cut by furrows which cross each other. As they grow older, their bright colour darkens; the yellow, which shone even to a great distance, changes into brown, and the bluish gray of the lepraria insensibly acquires a tint of dusty black. The extremities of the older coverings approach and mingle together; and upon this dark ground are formed new lichens of a circular form, and of a dazzling whiteness. It is thus that an organic net-work is wrought in successive layers. Where the majestic oak now raises its aerial head, slender lichens once covered the bare rock. Moss, grasses, herbaceous and shrubby plants, fill up this long interval, the duration of which cannot be calculated: In the torrid zone, the portulaca, the gomphrena, and other low plants inhabiting the shores, supply the place, and produce the effects of the lichens and mosses in the northern climates."

This interesting observation tends to establish certain epochs in the history of the successive propagation of the plants which now cover the earth: Without doubt, where vegetation had already thrown her verdant mantle over the primary and secondary mountains, the ternary lands might still be seen scarcely dried, covered with muddy slime, and sown with some languishing plants, rushes, mosses, and thick bushes of osier and willows. The Greeks alleged, that men, animals, and plants, inhabited the mountains long before they spread themselves over the plains, and along the coasts [y].

[y] Plat. de Leg. iii. Oper. ii. p. 677. Edit. Serran. Aristot. Meteorol. ii. 13. Strabo, Geog. i. and iii. 407. ed. Cas.

Tacitus describes Germany as full of inaccessible marshes, which are now in a great measure dried up. Rudbeck himself admits, that according to the tradition of the country, the low parts of Scandinavia presented the same aspect [2]. Thus, history appears to confirm the hypothesis so ingeniously developed by Lacepede and Ramond [3]; according to which, we ought to look upon the great chains of mountains as so many centres, whence vegetable, as well as animal population, was scattered over the rest of the globe. Epochs in the propagation of plants.

In truth, the chains of the Alps of Mount Atlas and Mount Taurus, the central upland plain of Asia, that of Southern Africa, the Andes, the Allegany mountains, seem to be the native land of the vegetables which cover the countries lying at their base. To these grand centres of the vegetable kingdom, the progress of discovery will, ere long, add the upland plains or chains of mountains which are supposed to occupy the interior of New Holland and the north-west parts of America. Primitive centres of vegetation.

It would, we conceive, be extremely unwarrantable to reduce these centres of vegetable and animal life to one single centre, as has been attempted by several philosophers, led away by an undue regard to mythological traditions, or to their own interpretation of the sacred records. Could the organic energy by which matter was animated, have acted originally only upon one point of the globe? Would not nature, upon the banks of Senegal, have exercised the same power as upon the shores of the Ganges? Why should corn have sprung up in Tartary before it grew in Europe? Why have not Spain and Italy produced wild olives, when Persia, which is much colder, is covered with them? The pretended migrations of plants are very much exaggerated. We are willing to suppose, for example, that Europe has received wheat and barley from Tartary, the walnut tree from Persia, the olive from Syria, the vine from the borders of the Caspian Sea; in short, we accumulate histori Migration of plants.

[2] Rudbeck, Atlantica, i. p. 45. Torfæi. Hist. Norweg i. p. 111.

[3] Memoires de l'Institut et Annales du Museum

cal proofs, to shew that all our useful plants come from Asia[b]; but all these observations of the ancients relate only to the *cultivation* of a plant, and not to its origin. Lucullus, without doubt, was the first who brought from Cerasus, in Pontus, the cherry trees since cultivated in Italy; but, in relating this fact, Pliny tells us that the cherries of Lusitania were the most esteemed in Belgic Gaul, and that Macedonia produced a particular kind[c]. Would he have spoken in this manner, had the cherry trees of Macedonia and Lusitania been propagated from those of Pontus? The same author, however, seems to allow that the vine was indigenous to Gaul[d]. Ancient traditions concur in ascribing the first cultivation of wheat to Sicily or to Attica, a cultivation contemporary with the first attempts at legislation[e]. A kind of rye, known under the Celtic name of Arinca, from which the term used in Dauphiny, "Riguet," is derived, was a native of Gaul[f].

These examples, which it were easy to multiply, prove that the farinaceous plants, and in general the vegetables of Europe, may dispense with the honour of a foreign origin. On the other hand, we cannot deny that the migrations of man have a singular influence upon the geographical extension of plants. Not only has man intentionally carried the coffee-tree from Arabia to the West Indies, and the potato from America to the shores of Europe, but even the accidental introduction of a foreign grain into a bale of merchandize, has propagated many plants from the Brazils to the environs of Lisbon, and some of these, in their turn, from Portugal to the coasts in the neighbourhood of Falmouth and Plymouth in England.

[b] Heyne, Opusc. Acad. vol. i. p. 330-383. Linné, Coloniæ Plantarum, &c. Sprengel, cité par Humboldt, Tableaux de la Nature, i. Dureau de la Malle, Aperçu de l'Origine des Plantes Céréales, Annales des Voyages, x. 321, *sqq.*

[c] Plin. lib. xv. cap. 25.

[d] Id. Plin. xiv. 3, 9.

[e] Pausan. in Arcad. Callim. Hymn. in Cerer. Plin. vii. 56.

[f] Plin. xviii. 8.

There are in the dissemination of plants several singularities difficult to account for and even to define. Some plants appear to live in society, and occupy exclusively large tracts of ground, from which they banish all other vegetables. We can trace through Jutland, Holstein, Hanover, Westphalia, and Holland, a long chain of hills, entirely covered with common heath, and the Erica tetralix. The farmers have opposed for centuries, but with little success, the inroads of these vegetable hosts [g]. Sociable plants.

It is singular that the genus called Erica, is found only upon one side of our planet. Of the 137 species of heaths at present known [h], there is not even one to be met with in the new continent, from Pensylvania, and the coast of Labrador, to Nootka and Alaschka. They appear even very rare in Asia. We see, at other times, very singular leaps or intervals in the distribution of plants. Most of the forest trees of Europe, and even those which are the hardiest, disappear towards the Uralian mountains, and particularly towards the banks of the Tobolsk and the Irtych; they do not grow in Siberia, although under the same climate. The oak, the nut tree, and the wild apple, are subject to this common law. In vain should we search for one plant of them from the Tobol to the Daouria. The two first of these trees, however, reappear suddenly upon the banks of the Argoun and the Amur; the last occurs anew in the Aleutian Islands [i].

These remarks will have shown how difficult it is to mark with exactness the *regions* of botanical geography, a subject which, besides, appears to belong to that part of our work which contains a particular description of the different countries. We must here confine ourselves to a brief sketch of the general appearance and the advantages of vegetation in the different *zones* of the globe.

[g] Humboldt, Tableaux de la Nature, ii. 47.

[h] There are upwards of four hundred sorts or varieties. T.

[i] Georgi, Description de la Russie, 1re tome, 1re partie, p. 1015, et 3e partie, p. 1301, 1305.

Vegetation of the frozen zone.

The frozen zone contains few *species*, but, as in the short career of the Polar summer, vegetation is very rapid, these species comprehend a greater number of individuals than is commonly imagined. The verdure of the Polar summer is confined to the hills which have a southern exposure; though extremely short-lived, it is sometimes very brilliant. Besides mosses and lichens, we perceive ferns, creeping plants, and bushes with berries, such as the currant, the Rubus chamæmorus, the Rubus areticus, and the different sorts of Vaccinium, the resources and the luxuries of Siberia and Lapland. No where else are these fruits more abundant, or possessed of a finer flavour. The frozen zone also admits of some trees, particularly the birch and willow; but they remain always dwarfs, never growing higher than one or two feet. Such, however, is the privilege of the climate of Europe, that Lapland, which is almost entirely situated in the frozen zone, produces rye and leguminous plants, and would, according to De Hermelin, have supported fine forests, if an unwise economy had not procured their destruction. As the mosses and lichens of Iceland and Greenland are found upon the Alps and Pyrenees, it may be said that the frozen zone possesses no species peculiar to itself.

Vegetation of the temperate zone.

The northern temperate zone may, with relation to the vegetable kingdom, be divided into two parts; but the limit of these demi-zones varies according to local climate from the 50th to the 40th parallel of latitude.

Upon the boundary of the temperate and frozen zone begins the perpetual verdure of the pine and the fir, trees alike distinguished for the almost crystallized regularity of their form, and for retaining their vital warmth amidst the chilling rigours of winter; resembling in this latter circumstance the natives of the soil, whose moral resources have surmounted all the disadvantages of their ungenial climate. Several fruit trees, the apple, the pear, the cherry, and the plum, and certain vegetables, such as cabbage, pease, and radishes, grow better, or are more cultivated in the northern half of the temperate zone. Flax and hemp are

indigenous to it. The verdure is more brilliant there, particularly in the regions adjacent to the sea. As we advance, the oak, the maple, the elm, and the lime, gain the superiority over the pine and the fir. The more delicate fruits, such as the olive, the lemon, the orange, and the fig, and amongst the wild trees, the cedar, the cypress, the cork, more especially belong to the most southern part of the same zone. There is even a perceptible difference in the cultivation of vegetables beyond and within the 45th degree. Beans, lentils, and artichokes, appear indigenous to the south of this line; the onions there have less pungency. Truffles and many other delicate or aromatic vegetables, do not come to the same perfection to the north of this parallel.

Country of the vine.

The vine and the mulberry occupy the space between the 30th and 50th parallels; we may even say, that if the vine has followed civilization to the 50th degree and beyond it, it is only in France, in Germany, and in Hungary, a part of the globe too small to be considered otherwise than as an exception. The true country of the vine is to the southward of the 45th degree. The people who live to the north of this parallel extort from the soil, by the application of labour and of skill, what nature lavishes away with spontaneous profusion on the ignorance of the vine-dressers of Italy, and the indolence of those of Spain. Peaches, apricots, almonds, quinces, chesnuts, and nuts, are equally injured in their growth as they approach the neighbourhood either of the tropic or of the polar circle.

Cultivation of corn and grain.

Oats and barley are the kinds of corn which best bear the cold; barley, in particular, seems to lengthen or shorten the period of its vegetable life according to the duration of summer. In Lapland, and at Olekminsk in Siberia, it ripens in seven or eight weeks; notwithstanding this astonishingly rapid growth, it is sometimes overtaken by the frost of the Siberian winter [k].

Between the 60th and 40th degrees, the more fortunate

[k] Georgi, Description de la Russie, iii. 716.

husbandman fills his granaries with rye, wheat, millet, and buck-wheat; rich in these treasures, he envies not the more southern climates their rice, their maize, and other grain of a similar kind. Grain of this description, less favourable to the health and vigour of man, can however be raised in the latitude of 50°; but a wise system of rural economy prefers the culture of less uncertain crops.

General aspect of the warm temperate zone.

The European born to the north of the Alps, is ready to form a false idea of the character of the zone lying between the 40th and the 25th degrees of latitude. Leaving our majestic forests of oaks, and our delightful orchards, where his feet have been accustomed to tread upon a verdant turf, he crosses the Alps, the Cevennes, the Pyrenees, and, struck with the naked and scorched appearance of Provence, of Italy, or of Spain, he instantly figures to himself beyond the Mediterranean vast seas of sand in Africa, and is tempted to imagine that all this zone is naturally destitute of trees. In this opinion he is wrong. It is true that in all the countries adjacent to the Mediterranean, and where secondary calcareous earth predominates, a part of the surface of the soil is composed only of barren rocks. The beautiful picturesque appearance of Italy is chiefly produced by the agreeable contrast which is presented by the naked rock, and the lively vegetation scattered here and there over the surface: but wherever this rock, from being less cracked and chinky, retains the water at the surface of the ground, as is the case upon the borders of the enchanted lake of Albano, Italy has its forests of oaks as branchy and as green as those which we admire in the north of Europe[1]. The great deserts, or seas of sands in Africa, present merely a local phenomenon, and one which is not peculiar to the zones, since similar deserts occur in Persia and Tartary, under a much less elevated latitude. If we admit the theory of M. Deluc, they formed the bottom of the ancient sea of the globe.

It must however be allowed that the warm temperate

[1] Humboldt, Tableaux de la Nature, i. 20.

zone, or that from the 40th to the 25th parallel, presents in general less constant humidity, and a less beautiful vegetation than the cold temperate zone. The only exceptions occur in the United States and in China, regions where, in consequence of their peculiar geographical situation [m], the climate of the cold temperate zone and that of the torrid zone run so much and so frequently into each other as to produce a most agreeable mixture of the northern with the equatoreal vegetation.

Vegetation of the torrid zone.

The torrid zone possesses vegetable wealth, which we should in vain expect to realise in the other regions of the globe. It is in that zone that the most juicy fruits, and the most pungent aromatics arrive at perfect maturity, and vegetation of every kind is distinguished for stateliness, variety, and splendour. There the glowing beams of the sun raise the plant into a shrub, and the shrub into a tree. The simple sap, which in other regions merely flows in the veins of vegetables, there ripens and exudes through the stem under the form of balms, gums, and juices, which either form powerful remedies against the attacks of disease, or gratify the fastidious and stimulate the blunted taste of the voluptuous European. What a paradise! if we could but transport thither civilization and morality. It is there that the ground produces the sugar-cane, the coffee-tree, the palm, the bread-tree, the pisang, the immense baobab, the date, the cocoa, the vanilla, the cinnamon, the nutmeg, the pepper, the camphor-tree, &c. &c. There are also various sorts of dye-wood, and particular kinds of corn, such as the durra, the holcus, the cambu, the kebru, which almost exclusively belong to the torrid zone; while this zone is not destitute of any species which grows under a less warm sun. The plant which in Siberia vegetates in the plain is found at the highest summits of the mountains under the line, and the sides of these same mountains correspond to the climate of the temperate zone.

The appearance of vegetation under the equator en-

[m] Compare Book xvii. p. 406.

Appearance of vegetation in the torrid zone.

chants the imagination; it is there that plants display the most majestic forms. As in the frosty regions of the north the bark of the trees is covered with lichens and moss, so between the tropics the cymbidium, and the fragrant vanilla adorn the trunk of the anacardium, and of the gigantic fig-tree. The fresh verdure of the leaves of the pothos forms a contrast to the flowers of the orchis, variegated by a thousand different colours. The bauhinia, the climbing passion-flowers, and the banisteria, with its flowers of gold, twine around the trunks of the forest trees. Delicate flowers spring from the roots of the theobroma, as well as from the thick, hard, and blackened rind of the gourd and of the gustavia. In the midst of this exuberant vegetation, and this confusion of climbing plants, it often costs the naturalist trouble to ascertain to what stem the leaves and flowers belong. One single tree, adorned with the paullinia, the bignonia, and the dendrobium, forms a group of plants which, separated from one another, would cover a considerable space[n]. In the torrid zone, the plants which are most abundant in juices, present a brighter verdure, and larger and more magnificent leaves than in the northern climates. The vegetables which live in groupes, and which render the countries of Europe of so monotonous an aspect, are very seldom to be met with in the equatoreal regions. Trees twice as high as our oaks are decked with flowers as large and as beautiful as our lilies. Upon the shady banks of the Madalena, in South America, grows a climbing aristolochia, the flowers of which are four feet in circumference. Children amuse themselves by covering their heads with them. We may add to this description, the gigantic forms of the baobabs, whose circumference sometimes extends to 80 feet, and the elegantly bold shape of the eucalyptus, and of the gummy palm trees, which, rising to the height of from 150 to 180 feet, form aerial porticoes above the forests.

The extraordinary elevation to which whole tracts of

[n] Humboldt, Tableaux de la Nature, ii. 60.

country rise, under the tropics, and the cold temperature of that elevation, present to the inhabitants of the torrid zone an extremely singular prospect. Besides the groups of palm and banana trees, they see also around them the vegetable forms, which appear to belong only to the regions of the north. Cypresses, firs, and oaks, barberries and alder trees nearly resembling ours, cover the mountainous districts of the south of Mexico as well as the chain of the Andes under the equator.

The temperate southern zone.

The southern temperate zone should now terminate the phytographical description of the globe, could we venture to assert, that, with reference to vegetation, such a zone does exist. It appears that the three extremities of America, of Africa, and of New Holland, included in this zone, contain only vegetable colonies, which, taking their origin from the torrid zone of each of these regions, have spread themselves towards the south. It is therefore probable that the vegetation of these three continental extremities, even were it better known than it is at present, would present to us a few detached local scenes rather than any general picture.

BOOK XXI.

Continuation of the Theory of Geography. Of the Earth, considered as the residence of Organic Beings.

SECTION II.

OF THE GEOGRAPHICAL DISTRIBUTION OF ANIMALS.

General views.

The unknown power which first put in motion the springs of animal life, and which continues to keep them in play, was certainly not confined to one particular region of the globe. Matter, everywhere, must have acquired animation at the sound of the Creator's voice; the elementary particles, while attracting each other, and ranging themselves in fibres, muscles, and bones, must have every where presented the spectacle of that *spontaneous generation*, which is probably, at all times, ushering into existence millions of aquatic and other animalcules, some of them so minute as appear to the most powerful microscope merely as a small point or globe, destitute of organs[a]. It is difficult to conceive that there exists in this original tendency of matter towards organization, differences founded upon the geographical situation of places.

Spontaneous generation.

Zoophytes.

Zoophytes are so imperfectly known, and so difficult to class, that we cannot say whether each maritime region possesses any species peculiar to itself. Coral, externally an animal and internally a rock, madrepores, and millepores, which, on the contrary, have a stony covering, seem to exist only in the regions adjoining to the tropics, in the seas warmed by the rays of a vertical sun. There are three or four great seas of coral upon the globe: first, that part of

Seas of coral.

[a] Compare Cuvier, Tableau Elementaire des Animaux. p. 663.

the great ocean where flat islands appear, such as those called the Friendly Islands, New Caledonia, the Solomon Isles, or Isles of Danger, and in general those tracts of sea lying between the different parts of the Oceanic division of the world. It is there that the mariner is in continual danger of striking against some rock of coral, shooting perpendicularly up from an immense depth. The second region extends from the coast of Malabar to that of Madagascar and Zanguebar. Our Mediterranean forms the third region; but the valuable coral which it furnishes, and which is in great request from Africa to Japan, essentially differs from the coarse substances of which the islands in the southern sea are composed. The Gulfs of Arabia and of Persia, if we credit the ancients, are peopled with subterraneous forests of Zoophytes [b]. The sea of the Antilles, and the Gulf of Mexico, ought to contain a great many madrepores. But who is sufficiently acquainted with the different *holothurae*, *star-stones*, *medusae*, and other fugitive embryos of aquatic beings, to assign to them their native region? The indefatigable voyagers, Peron and Lesueur, who so carefully observed the changeable and delicate forms of the zoophytes [c], found the abode of the species *pyrosoma* confined to one particular region of the Atlantic Ocean; and they imagine that each description of zoophyte has its place of residence determined by the temperature necessary to support its existence.

The ocean also contains monsters, which it is dangerous to observe too near. When shall we come to distinguish the different kinds of polypi or hydras, with exactness sufficient to determine the boundaries of the tracts which they respectively occupy at the bottom of the ocean? We think it probable that the size of the polypi varies with the depth of the seas where they live. If we certainly know that the Straits of Messina, and the English Channel, contain some which have arms ten feet long, why Polypi.

[b] Plin. Hist. Nat. xiii. 25.

[c] Voyages aux Terres Australes, i. 492. et l'Atlas, pl. xxix.—xxxi.

should we treat as fabulous those very circumstantial accounts, both of the ancients[d] and the moderns[e], which speak of polypi taken in the Mediterranean, in the Atlantic, and in the Indian seas, whose arms, when accurately measured, were found to be from 30 to 40 feeth in length! Would it not be consistent with the rules of sound criticism, to suspend our judgment respecting the monstrous *krakens*[f] of Norway, said to be half a league in length, the existence of which several respectable[g] naturalists have conceived to be established by recent observations?

Zoophytes exhibit the first actings of creative power; they may be considered as confused masses of beings, animated with an incipient principle of life, but not yet existing separately. The *molluscae*, whether naked or testaceous, have acquired a real individual existence. Accordingly, their different species belong to different countries: the shells of Timor are met with upon the coasts of New Holland only as far as to the south-west point; and the shells of Van Dieman's land, such as the *Haliotis gigantea* and the *Phasianellus*, diminish in size as they follow the coasts of New Holland, to king George's Straits, and entirely disappear beyond them[h]. The pinna marina, whose glossy filaments outshine silk, thrives only in the Indian seas, and in the Mediterranean. The pearl oyster attains perfection no where except in the equatoreal seas. But the natural arrangement is often subverted; the ships to which the shells adhere, transport them from the one pole to the other. It is in this way that the waters of Holland have been peopled by that teredo navalis which is so destructive to vessels[i].

Molluscae shells.

The calcareous secretion of the Zoophytes is rock or stone the very moment that the animal dies. The calcare-

[d] Plin. ix. 30. Aelian Hist. Nat. xiii. 6.

[e] Aldrovand, de Molluscis, Part vii. c. 2. Johnston, de Exanguib. Aquat. ib. i. tit. 2. c. 1. Swediaur, Journal de Physique, 1784, vol. ii. p. 284. *sqq.*

[f] See the article Norway, in this work.

[g] Bosc. Hist. Nat. des Vers, i. p. 36. Montfort, Histoire des Mollusques, ii. 71, 153, 218. Pennant, British Zoology, iv. tab. 28. fig. 44.

[h] Péron et Lesueur, Annales du Muséum d'Histoire Naturelle, xv.

[i] Sellii, Nat. Hist. teredin Utrecht, 1733.

ous secretion of testaceous molluscæ or shells, forms rock only when decomposing. The structure of corals and madrepores is grained, that of shells is lamellated or stratified. These animals, from their being destitute of sensibility, seem closely allied to the mineral kingdom.

We now advance to another order, which may be viewed as belonging to the vegetable kingdom,—the order of insects, in which worms occupy the bottom of the scale. Insects which, as they pass through the states of larva and chrysalis, remind us of the successive development of roots, stalks, and flowers; insects, which may be termed winged and animated flowers, indicate already, in their complicated organization, some obscure traces of sensibility, although irritability still predominates. It is in the midst of the most exuberant vegetation—it is in the torrid zone—that the strongest and the most splendid insects are to be seen; such as the butterflies of Africa, of the East Indies, and of America, whose brilliant colours rival the lustre of metals. There also, and particularly in South America, the forests, peopled by millions of glow-worms, present to the eye of the benighted traveller the scene of an immense conflagration. The termes of Africa, named also the White Ant, builds solid hillocks; and the spider of Guyana attacks even birds with success. The *limulus gigas*, the largest of all aquatic insects [k], is also an inhabitant of the equator, as its vulgar name, *the Crab of the Moluccas*, indicates. Certain kinds, such as gnats, bees, and flies, appear to be equally distributed over the whole of the globe. The short polar summer hatches a multitude as innumerable as the heats of the torrid zone: the musquito, which torments the traveller on the banks of the Oronooko, resembles that which buzzes in Lapland. Wherever man has not drained the marshes, and cleared the forests, insects reign with resistless sway. History has recorded several examples of towns and countries rendered uninhabitable by the multitude of bees, wasps, or gnats [l]. Armies and whole tribes

Geographical distribution of insects.

Countries rendered uninhabitable by insects.

[k] Cuvier, Tableau Elémentaire, 452.

[l] Herod. v. 10. Plin. viii. 29-58. Ælian, xvii. 35. Pausan, in Achaicis. Compare, Bochart, Hierozoicon, l. iv. c. 13. vol. ii. p. 539, *seq.*

have been compelled to fly before these feeble insects, rendered invincible from their numbers.

The secretions of insects do not resemble substances of the mineral kingdom, like those of the zoophytes and molluscæ; they have the character of vegetable juices. But these secretions, as well as those of the polypus coral, appear to be the effect of blind instinct, rather than of sensations similar to those of the more perfect animals. The admirable industry of the bee is not to be ascribed to the acting of a free and separate will.

The orders of zoophytes, molluscæ, and insects advancing gradually in perfection, comprehend animals *with white blood, and no vertebrae*, and which, having few or no organs of sensibility, appear to constitute in the animal kingdom a sort of hemisphere diametrically opposite to that of animals *with vertebrae and red blood.*

This second series of the animal kingdom commences, like the first, in the bosom of the ocean, that cradle of all primitive organizations.

Fishes. Fishes, although occupying the lowest degree of the scale, are completely distinguished from inorganic nature: they display the commencement of an internal ossification, mixed indeed with some traces of those external secretions, those solid coverings, which belong to animals destitute of vertebræ. Fishes, having neither the blind instinct of insects, nor a high degree of the voluntary instinct of the mammiferous tribes, appear inferior even to several white blooded animals, although they form part of an order superior to that to which these animals belong. The animal kingdom does not present to our view one unbroken progressive series, but two great series, each composed of several progressive orders; so that the gradations in improvement of organization are not continued from genus to genus regularly through the scale, but only from the whole of one order to the whole of another.

The want of activity which we have just remarked in fishes, renders it probable that every basin of the ocean has its particular tribes, which are born and die there: we

know the stations of some species of fishes. Thus the cod which are distributed over all the northern seas, between Europe and America, congregate chiefly upon the great banks of sand to the south-east of Newfoundland. Pursued by twenty thousand fishermen, the cod propagates with astonishing fecundity; it has been calculated that each female carries in its ovary more than nine millions of eggs[m]. Upon the situation of some fishes.

The coryphenæ and the chatædons are met with only in the torrid zone. There are various species of these kinds, which, on account of their brilliant colours, have received the name of giltheads. These are the most active enemies of the flying fish, which, like them, are found only between the tropics, or, at farthest, towards the 40th parallel of latitude. These species are observed both in the eastern ocean, and in the Atlantic; but probably of different species. We should imagine that the electric fishes are confined to the torrid zone; the electric gymnotus, indeed, belongs exclusively to America; and the "trembler," or the *silurus electricus*, to the rivers of Africa; but the *torpedo*, or cramp fish, is dispersed over all the seas. Our knowledge of the productions and the temperature of the ocean, must, from its vast extent, and its unfathomed depth, be extremely imperfect. On many coasts no fisheries exist, and from those which have been established, on others, little accurate information can be gained. No analysis, even of the magnificent works of Lacepede, would enable us to unfold a correct general view of the subject; and the description of each particular sea is reserved for other volumes of this work.

The migration of fishes is occasioned by their being impelled to seek for shallow water, in order to deposit their spawn. Thus the herrings, coming from the bottom of the frozen sea, proceed every year to the coasts of Ireland, Scotland, Norway, Sweden, Denmark, Holland, and the Migration of fishes.

[m] Cuvier, Tableau Elementaire, p. 337.

United States[n], as well as to those of Kamstchatka, and the neighbouring islands[o]. It seems to be proved that immense shoals of these fishes mechanically follow the direction of the chains of submarine banks and rocks which they meet with in their progress. The variations, both real and pretended, which these migrations experience, seem therefore to depend upon local causes, which we shall point out in another place. *Tunnies* migrate regularly every year from the Atlantic ocean to the Mediterranean; a fact before observed by the ancients[p]. Besides these annual migrations, which, to a certain extent, are completely ascertained, the currents of the ocean must occasion others which we have not the means of observing. Fishes in general appear to suffer severely from a sudden change of temperature[q], which leads us to infer that the species which live near the surface of the sea must be confined each within a particular region. On the other hand, the observations of Biot and Laroche, by demonstrating the admirable property of the organs of respiration in fishes, by which they can inhale the more oxygen the lower they descend, seem to remove all limits to the migrations of species which live in the lower parts of the sea[r].

Fresh water fishes.

The fishes of lakes and rivers are still less susceptible of a geographical classification. The kinds *cyprinus* and *perca*, of which carp and perch are the representatives, people almost all the rivers of the temperate zones. The sturgeon is found in the smaller inland seas, such as the Baltic, the Caspian, the Black sea. The large species[s], common in the Wolga and the Danube, are in their turn surpassed in size by the *silurus glanis*, the giant of river fishes. The voracious pike, and some other species, often

[n] Gilpin upon the Migration of Herrings, in the Transactions of the American Society at Philadelphia, ii. 786.

[o] Krachenninikow, Descript. de Kamtchatka.

[p] Oppian, Halieutic. III. v. 633, *sqq.*

[q] Provençal et Humboldt, Mémoires de la Société d'Arcueil, ii. 398.

[r] Biot, ibid. p. 487.

[s] Acipenser Huso.

inhabit subterraneous seas, which communicate with the atmosphere only by small openings. A circumstance more worthy of occupying a place in a general description, is the presence of some sea fishes, such as the *cabelian*, a species of cod fish, in Lake Winnipeg, in the interior of North America [t].

There are some fishes which occasionally forsake their native elements: eels traverse the meadows; and upon the coast of Coromandel, a kind of *perch*, *Perca scandens*, climbs up the palm trees [u]. Sonnerat observed fishes which live in warm springs of a very elevated temperature. Natural history will pardon us for not distinguishing from fishes those equivocal beings which, with the warm blood of mammiferous tribe, possess a combination of those forms which are equally characteristic of the fish and the quadruped. Fish in singular situations.

The whale, the narval, or sea unicorn, the *cachalot*, or spermaceti whale, the *dolphin*, the sea-horse, the *phoca*, or sea-calf, inhabitants both of the land and the water, form, in the progressive improvement of their organization, the link which connects two different orders. Whales are in very few respects distinguished from fishes, and there are phocæ that have been mistaken for otters. The more complete the ossification, and the more the organs are detached, the greater is the sensibility. Phocæ and lamentins manifest some traces of social affection. Cetaceous animals.

As both the cetaceous and the mammiferous amphibious kinds of fishes require frequently to breathe atmospheric air, it is highly probable that they are confined to certain climates. The phocæ of the South Seas are of different kinds from those which inhabit the waters of the north [x]. The sea-lion met with in the neighbourhood of Kamtchatka differs essentially from that which swims in the Green- Geographical distribution of cetaceous animals.

[t] Goldson, Remarques sur le Voyage de Fuente, dans Sprengel, Choix des Voyages, &c. iv. 16. (In German.)

[u] Daldorf, Transact. of the Linnæan Society, iii. 62.

[x] Péron, Annals du Muséum, xv. 300.

land Seas[y]. The phocæ vitulinæ, which are alleged to exist in the Caspian Sea, in the lakes of Aral, Baikal, and Ladoga, appear to be a species allied to the otter, and different from the marine phocæ. And thus are we relieved from the necessity of admitting those physical revolutions by which it is asserted that they were brought into those inland waters, as if nature could not produce phocæ every where. The great whale of the Northern Seas, though it formerly entered the Mediterranean[z], has scarcely been able to approach the equator: the whales of the Southern Ocean are probably of a different race. The large-headed cachalot, which inhabits the equatoreal regions, particularly the Indian Ocean, and from which we procure the ambergrise, differs materially from the great cachalot of the frozen seas.

Remarks upon reptiles.

Amongst terrestrial animals, reptiles occupy the lowest rank. Their organs are indistinct and imperfectly developed, and some organs they want entirely; a thick shield or a scaly skin envelopes their body; their bones are soft; the vital force, distributed through all their members, has no centre of energy; finally, the animal, when cut into pieces, is immediately reproduced. All these characteristic marks indicate a first attempt of nature, an imperfect disengagement from inert matter. Reptiles, accordingly, appear to increase and multiply in mud, warmed by the vertical rays of the sun: The crocodile of Africa, the Gavial of the Ganges, and the different caymans of America, are the giants of the lizard kind. It is in the warmest regions of America, and the oceanic countries, that the serpents roll themselves up in immense coils, or conceal a deadly poison under their fangs. The tortoises, which feed upon the sea-weed at the bottom of the ocean, cover the sands only of equatoreal countries with their numerous eggs.

[y] Steller, Nov. Comm. Petrop. ii. 360, 366. Otto Fabricius, Fauna Groenlandica, p. 7.

[z] Plin. ix. 3.

In creating birds, nature has reproduced the order of insects, but with more simplicity of structure, and greater power and liberty of locomotion. Their bones, more hard and more numerous than those of fishes and reptiles, mark a more perfect organization. The wings with which they are provided seem to assign to them the whole atmosphere as their domain; but the plumage in which they are clad, and which, like vegetation itself, varies according to climate and temperature, proves to us, that these animals, apparently so free, are still subject to certain geographical laws. Even those whose robust constitution would allow them to disperse themselves far and wide, seem to be attached, both by taste and affection, to the districts where they were born. Thus, the condor, and the king of vultures, which soars above the summit of Chimborazo itself, never forsakes the chain of the Cordilleras of Peru and of Mexico: the vulture, and the great eagle, never remove from the ridges of the Alps. The sea eagle, or ospray, is perhaps distributed over the whole of the globe. In the natural order of Passeres, travellers often err, by confounding the foreign species with those of Europe—thus, the *Calaos* of Africa and India differ from our ravens, and the *Manakins* of America are not our tom-tits, though possessing some traits of resemblance. The torrid zone, also, exclusively contains the various species of *Parroquets* common in America,—of *Cockatoos*, found only in the East Indies,—of *Loris*, most beautiful in the islands to the south-west of Asia,—and of *Aras*, which last are all from America. The celebrated *Bird of Paradise* is never met with beyond the limits of a very narrow region of the torrid zone, that is, New Guinea, and the neighbouring islands. Of the birds which cannot fly, every equatoreal region, insulated by the sea, has produced its particular kinds: The *Ostrich* of Africa and Arabia, the cassiowary of Java, of the neighbouring islands, and of New Holland, and the Touyou or Ostrich of Brazil, exhibit, in very distinct species, the same general features of organization. The smaller birds in the tropical

Birds in a geographical point of view.

Birds of the torrid zone.

countries are adorned with the most splendid colours, their plumage vies with the metallic brilliancy of the insects in the same zone.

Birds of the temperate zone.

The temperate zone of birds reaches in our hemisphere from the 30th to the 60th parallel. Within these boundaries the various kinds, and even some species, are no longer confined to regions distinctly marked, and have no particular fixed countries. Besides, man has either transplanted, or drawn in his train with him, as he wandered, several species previously to be found in one particular country. The most remarkable geographical phenomenon is the annual migration of swallows, of storks and cranes, which, at the approach of winter, abandon the northern countries of Europe to visit Italy and Spain, and even Africa. Some species of swallows plunge themselves into lakes and marshes, where they remain in a dormant state during the winter[a].

Annual migrations.

Birds of the frozen zone.

The frozen zone has few species peculiarly belonging to it; amongst these is, the *Anas mollissima*, whose nests furnish the eider down. But we should consider this aquatic bird rather as frequenting the shores of the frozen seas. The *Strix lapponicus*, and the *Tetrao lagopus*, live upon mountains covered with perpetual snow.

Sea birds.

Each grand maritime division of the globe has its peculiar birds. The *Albatros* flits along upon the waves as soon as we approach the 40th parallel of latitude. The sea swallows, and the tropical birds, never forsake the torrid zone; their species probably differ from the one ocean to the other. The *Penguin* of the Northern Pole differs from the *Manchot* of the South Seas. These birds without wings, may be considered as the last and lowest of the order to which they belong.

Quadrupeds.

We now come to an order of animals much more perfectly organized than any of those which we have hitherto con-

[a] Compare Guenau, in Buffon Histoire des Oiseaux, vol. xvii. p. 857. Daines Barrington, Miscellanies, p. 225. Mem. of the American Academy of Boston, i. p. 494; ii. p. 93, *sqq.*

sidered. It is particularly interesting to observe the geographical distribution of the various kinds of quadrupeds in the different zones, and on the two continents. This inquiry has already thrown great light upon the history of the earth, and is connected also with the history of man[b].

Their migrations.

In the migration of animals, we have not so much to attend to their *active* power, or the energy of their organs, as to what may be termed their *passive power*, or their capacity of resisting changes of temperature. Frequently, out of a whole genus, one species only is endowed with this capacity. Another species of animals again owes its extensive distribution solely to the care of man, who knew how to master it, and who carried it along with him to the very extremities of the globe. The external organs of animals undergo great changes, merely in consequence of their domestication—difference of climate produces others not less remarkable. As to the wild animals, they are directed in their migration, by the abundance or the scarcity of food. The carnivorous ones find almost every where their natural food, and when it fails them, they have recourse to vegetables; for this reason they must have spread themselves to a great extent. Those which cannot support great cold, have been unable to cross from the old to the new continent, because the only direct mode of communication between these two continents, is that furnished by the arctic ice. There are many different species of animals, whose residence history proves to have anciently been in much colder climates than those which they now inhabit: Sometimes the continual inroads of man have either destroyed them or driven them away: Sometimes the progress of agriculture, by clearing the forests, has bereft them at once of their range for food, and their place of shelter.

Animals generally spread over the globe.

Several quadrupeds, by their almost general distribution, baffle every attempt at geographical classification. These quadrupeds are either in a state of domestication, such as the dog, the cow, the sheep, the goat, the horse, the ass, the

[b] Zimmerman, Geographical Zoology, 3 vol. in 8vo. 1768, in German.

pig, and the cat; or in a wild state, as the fox, the bear, the hare, the rabbit, the stag, the deer, the squirrel, the rat, the mouse, and the ermine. Amongst these animals, however, there are some which do not live in the frozen zone.

The dog. The *Dog*, the faithful companion of man, has followed him into every climate; in many countries he is the only domestic animal, and supplies the place of the horse and the ox. Towards the equator, as well as towards the pole, he loses his voice; his barking degenerates into a growling noise. This species is distributed as far as New Holland[c].

The ox. The *Ox* lives as far as the 64th degree, and in Lapland even under the 71st. This animal appears to be a native of the warmest part of the temperate zone of the old continent; it is there that he attains the greatest degree of strength and courage. But in the more humid and cold climates, as Gallicia, Holstein, and Iceland, the ox grows much larger, and the cows give more milk. In Iceland, it is in the valleys lying to the north, and under the 65th degree of latitude, that the cattle thrive best. The cows there have no horns, but yield abundance of milk. The ancient Icelandic colony in Greenland, exported butter, salt beef, and hides[d]. The benevolence of Providence, by rendering this most useful species capable of supporting almost every climate, has thus enabled it to follow man to the remotest boundaries of animated nature.

The sheep. The *Sheep* and the *Goat* equally support the polar cold and the heat of the torrid zone. Goats are very numerous in Norway and in Iceland. The original race of sheep, the *Argali*, or the *Mouflon*, still exist, if we may credit Zimmerman, in all the great mountains of the two continents. The *Capricorn*, and the *Ibex*, or *Wild Goat*, which are the ancestors of the common goat, inhabit the highest summits of the two continents.

[c] Collins' Account, &c. p. 567.

[d] Speculum regale, 188, 191, 200. See the account of ancient Greenland in our first volume.

The *Horse*, which did not exist in the new continent before the arrival of Europeans, is spread in Europe, and in Iceland, as far as beyond the polar circle. In Asia the horse is scarcely found beyond the 64th parallel; in America the race has spread to the country of Patagonia, the climate of which, under the 50th degree of south latitude, answers to the climates of the northern hemisphere lying under the 60th parallel. The horse.

It appears to us, that there were in the old continent at least *three original races of horses*. The first, and the best proportioned, was originally spread between the 40th and 55th parallels, and probably came from Great Bucharia, from Persia, or even from Asia Minor[e]. The Tartar steeds, and those of Poland and Hungary, seem to have preserved the original form of the breed. In countries that are moderately damp and cold, and where there is rich pasturage, this race has become larger and stronger. The forms which are best developed have acquired that symmetry, and that noble warlike gait which mark the Danish, Norman, and English horses. These, however, have been mixed with the Arabian race. The third variety of the first race is a degenerate breed, produced by the deteriorating influence of a climate excessively damp; we may even trace the different degrees of this degeneracy. The horses of the country of Bremen have their feet worse made than those of Holstein and Jutland. As we proceed to East Friesland, their shape grows more and more clumsy. Three races of horses. Persian race.

The second race is small, and sometimes almost dwarfish; its characteristics are a compact square form, endowed with great strength, and surprising agility. It appears to derive its origin from the northern upland plains of Asia, from the steppes of Kirguises, although Pallas looks upon the wild horses of these countries as having come from the Studs[f]. This race, according to some accounts, appears to Mongolian or Scythian race.

[e] See the passages collected together by Bochart. Hierozoicon, b. ii. ch. 9.

[f] Pallas, Voyages, i. p. 376, in 8vo.

be spread in the north of India[g], in China, and in the islands of Japan. It is more certain that the breed is common in Russia and in Scandinavia. The Norwegians introduced it into Iceland and Scotland. It exists in the Danish island of Zeeland.

Arab, or African race.

The third race of horses is possessed of the most showy properties, being extremely swift, supple, vigorous, and mettlesome. We mean the *Arab race*, which undoubtedly has a common origin with that of Barbary, if it has not given birth to it. The Andalusian horses are its lineal descendants. The English say that their race horses are directly sprung from crossing the Arab with the Barb. History proves, that the Romans, the Saxons, the Danes, and the Normans, by introducing into Britain the various races of their respective countries, laid the foundation of the English breed. Private persons afterwards, from time to time, imported Arabian and Barbary stallions.

The ass.

The *Ass*, though far from being reckoned a very delicate animal, does not support cold so well as the horse. In Europe, it is rarely seen beyond the 52d parallel; and we do not believe that it can propagate at 60 degrees of latitude. The climates most favourable to the ass are those between the 20th and 40th parallels. There he grows large and handsome, is lively and docile, and is treated with kindness[h]. The wild ass is now found only in Tartary, where it never goes beyond the 48th degree of latitude.

The hog, its connection with the history of man.

The history of the *Hog* throws great light upon that of man. This foul animal is to be met with throughout the whole of the ancient continent, beginning at the 64th parallel of northern latitude. The *wild boar* is not found beyond the 60th degree. In the New World there were none of these animals, previously to its discovery by Columbus; they have been brought into it, and they live there from the 50th northern parallel to Patago-

[g] Pennant, Outlines of the Globe, ii. 239.

[h] De Grandpré, Voyage au Bengale, ii. 229. Niebuhr, Description de l'Arabie. Bochart, Hierozoicon, lib. ii. ch. 13.

nia. The hog is distributed over almost all the islands of the Great Ocean, where it is the chief domestic animal. Is it not evident from this single fact, that the islands of the Pacific Ocean have received their inhabitants from the south-east of Asia? We may, with equal justice, conclude, that had there been formerly a communication between America and the people of the ancient continent, this must have taken place, either at a period when man did not reckon the hog in the number of domestic animals, or under latitudes more northerly than those in which this animal can exist.

The *Cat*, now distributed over the whole globe, was not met with as a native of America. As this animal must have always accompanied navigators, its original absence in America greatly invalidates the pretended accounts of the Carthaginians, and especially the opinion that the Japanese maintained frequent commercial intercourse with the north-west of America. The cat, however, existed upon several islands of the Pacific Ocean before the arrival of Europeans. The cat.

The species of wild animals spread over all the climates of the two continents are very few; it is even doubtful whether there are any, except those which have been introduced into the new world by man.

Of all wild animals, the *Fox* is perhaps the most extensively distributed, and most easily assimilates to every climate. Vast troops of foxes inhabit Nova Zembla, and the shores of the Frozen Sea; and they are not less numerous in Bengal, in Egypt, and upon the coast of Guinea. The New Continent, says Zimmerman, is filled with them, from the northern parts of Greenland, under the 78th degree, as far as to Mexico, and from Mexico along the Cordilleras to the straits of Magellan. But travellers have applied this name at random; we have no satisfactory proof that there are any real foxes in South America. The fox.

Animals similar to the *Hare*, are found equally in Siberia and on the banks of the Senegal, upon the coasts of Baf- The hare.

fin's Bay, and over all the New Continent. But Buffon has expressed his doubts as to the identity of the American hares with those of the ancient continent; it does not at least appear that any real hares has been seen in South America. It is said that those of Greenland differ from ours only with respect to their skin, which remains always white[i]. The hares of that arctic country appear, however, to be of the species *Lepus variabilis*, which is known only in Siberia[k].

The squirrel. The *Squirrel*, according to Zimmermann, inhabits every part of Europe and Asia, from the extremities of Siberia to the kingdom of Siam, and is to be met with in Africa and the two Americas. But it appears that in every region of the world the species are different.

The rabbit. The *Rabbit*, being unable to live in the open air of the climate of Sweden, could not have emigrated into the New Continent by the countries in the neighbourhood of the pole. All the rabbits that are seen in the New Continent, have been brought thither by colonists, and have afterwards passed from the domestic to the wild state.

The stag. The *Stag* appears to be indigenous to both continents. It inhabits Europe as far as the 64th degree, and Asia to the 55th, and in some places even to the 60th degree. It is therefore difficult to conceive how it could have passed into America, as Zimmermann supposes. The stag of Canada, having horns without antlers, should, we apprehend, be considered as a distinct species[l]. Zimmerman also endeavours to prove, by numerous testimonies, that the stag is to be met with in the islands of Java, Sumatra, and Ceylon, as well as in Abyssinia, Guinea, and Barbary. But, in the first place, the stags in the islands to the south-west of Asia, in general imperfectly described, now appear to belong to the species of *Cervus axis*, and some of them perhaps

Otho Fabricius, Fauna Groenlandica systematice Sistens Animalia Groenlandiæ Occidentalis, hactenus indagata. Copen. 1780.

[k] Linné, Système, edit. 13. Gmelin, i. p. 100.

[l] Comp. Cuvier, Tableau Elémentaire, p. 160.

to the *Antelope oryx*[m]. And as to the existence of stags in Africa, since it is altogether denied by the ancients[n], and insufficiently established by modern authorities[o], it is probably confined to a few herds which had strayed from Asia, or perhaps broke loose from some royal or proconsular park. If there are any stags in Africa.

Shall we place the *Common Bear* in the number of animals which are spread over the whole of the globe? Zimmerman finds it in all latitudes, from the polar circle to the equator, and beyond it; but in the accounts which he quotes, we cannot always distinctly ascertain what variety is referred to. Common bears.

The *Black Bear*, which is the largest, appears to be met with in both continents. Its existence in North Africa has been clearly proved[p]; but the animals in America to which this name has been given, are not accurately described. As to the *Brown Bear* of the Alps, we shall assert nothing. It exists, without doubt, in Siberia, but it is not met with in the Aleutian Islands, and is rarely seen upon the coasts of the Frozen Sea, the abode of white or sea bears. As to the small bear, which the Norwegians name *myre-biorn*, or marsh bear, it seems to be a peculiar variety, confined within very narrow limits.

We have still to consider the geographical distribution of some small animals, concerning which we are extremely liable to err. Small quadrupeds.

The *Erminc*, or weasel, with a black muzzle, according to Zimmermann, is a native of every climate, being found in the Molucca Islands, in Guyana, and in Africa, as well as in Siberia, Lapland, Newfoundland, and Canada.

Rats and *Mice*, those troublesome parasites, embark on

[m] Valentin, quoted in the 2d volume, article Celebes.

[n] Herod. iv. 192. Comp. Plin. Arist. &c. apud Wesseling, ad Herod. loc. cit.

[o] Gataker, Miscellan. l. ii. cap. 8. Shaw's Travels, i. 170, quarto ed.

[p] Salmas. Exercit. Plinian. 220. Shaw's Travels, i. 177. Larcher, Histoire d'Herodot. iii. p. 488—490.

board our ships, and cross with impunity the equator, as well as the polar circles. It is to navigation that we must ascribe the extensive distribution of these two kinds of animals. On land, however, neither rats nor mice can support the cold of the frigid zone; there are none of them in Greenland, nor in the most northern part of Lapland; and in Siberia they are never observed beyond the 61st parallel.

From the preceding observations, we may draw the conclusion, that it is not yet certainly demonstrated that any species of animals, perfectly identical, has been distributed by nature over all the regions of the globe. In similar climates the organizations have assumed characters which nearly approximate, but never exactly coincide.

Quadrupeds distributed in the northern hemisphere.

There are some quadrupeds, which, from their capacity of supporting a very great degree of cold, are distributed in both continents without having ever passed the tropics; they belong to the cold part of the north temperate zone.

The rein deer.

The *Rein Deer*, of all known terrestrial animals, has its range nearest the pole. In Scandinavia, it can scarcely exist to the south of the 65th parallel; in Russia, from the greater coldness of the climate, it is found under the 63d; in Asia, it descends still lower, and roves into Chinese Tartary, among the Tunguses, beyond the 50th degree. This oblique line, drawn from Lapland to the land of Yesso, is very remarkable, because it nearly designates the physical frozen zone of the ancient continent [q]. The rein deer finds within this line only a species of moss [r], on which it lives. As the new continent is, if not colder, at least more uncultivated than Siberia, the rein deer, or the *kariboo* of Canada, which is the same animal, descends as low as the 45th parallel. The animal which has been termed the *Greenland stag*, is only a rein deer.

The white or polar bear.

The *White* or *Polar Bear*, an animal totally different from the common bear, and much more formidable, inhabits all the coasts of the frozen sea, and can cross from one country to another upon the floating ice. This mode of con-

[q] Georgi, Description de la Russie, iii. 1610.

[r] Lichen Rangiferinus, L.

veyance would be still more common to smaller animals. Hence the migrations of the different kinds of polar animals does not prove that the two continents were formerly contiguous. A bridge of ice, such as Cook found, is sufficient to account for these migrations.

The *Isatis*, or *Polar Fox*, an animal different from the common fox, appears to like the cold more than the rein deer, or even the white bear; for the bear retires, or conceals itself at the approach of the polar night; and it is only then that the isatis makes its appearance. This animal is not confined to the immediate vicinity of the pole, it advances as far as the Aleutian Islands and Kamtchatka on one side, and on the other to Iceland and Lapland. Isatis or polar fox.

Some other species, which could swim, may have passed over by the Aleutian Islands, or by Behring's Straits. Amongst these the river *Otter* should be named, which is found upon the old continent, from the 70th degree, to about the 20th, in the kingdom of Siam; but in the European countries on the shores of the Mediterranean, it is scarcely ever seen, having been probably expelled in consequence of the cultivation of the soil. In the new world, its principal range is between the 50th and 40th parallels. The *Marsh Otter* is confined to a still narrower range in the ancient continent, viz. the space between the 65th and 50th parallels of northern latitude. The *Marine Otter* seems to prefer the coasts of Kamtchatka, and the north-west of America, from the 65th to the 40th degree[*]. Otter.

The industrious and peaceful *Beaver* was once, perhaps, a native of all the countries of the globe, or at least of the whole of the northern temperate zone, for their habitations existed in Italy, in Persia, and in Egypt. This half civilized race of animals has been extirpated by man. In the new world, we still find small communities of beavers, from the 60th to the 30th northern parallel. But even in the deserts of Canada, they have withdrawn to a great distance from the residence of man. Beaver.

[*] Georgi, Description de la Russie, iii.

The marten.

To the *Marten* is assigned about two-thirds of the northern temperate zone, beginning at the 67th degree in Europe, the 64th in Asia, and the 60th in America. Zimmermann alleges that it is to be met with in Madagascar, in the kingdom of Anziko, and in Guyana; but the only circumstance which has been proved is, that the marten, properly so called, as well as the valuable *Sable Marten*, is dispersed over the Aleutian Islands, where the Siberian marten is never to be found [t].

Lynx.

The distribution of some other kinds of animals is uncertain. The *Lynx*, that tiger of cold climates, lives to the south of the polar circle; in the ancient continent, he appears as far north as the Pyrenees, and in Mongolia. We are but imperfectly acquainted with those animals of the new world, particularly of Carolina and of North Mexico, to which the name of *lynx* has been given.

The elk.

The *Elk*, an animal which is every day becoming more rare, seems to dread extreme cold, since in Europe it very seldom passes to the north of the 64th parallel; on the other hand, it is never found to the south of the 52d degree. In Asia, the farther we advance towards the east, the more does it range to the south. The American elk, though not much different, appears to belong to a particular race, as the genuine elk of Asia does not pass Kamtchatka and the Kurile islands [u]. The region of the elk in America begins under the parallel at which it terminates in Europe, that is, to the south of Hudson's bay, and extends to New England, or perhaps in the interior as far as to the Ohio.

Squirrels, mountain rats, &c.

The *Flying Squirrel* never ventures farther either north or south, than the limits of the fir forests in which it makes its abode. The *Mountain Rat* follows in Europe the chain of the Alps and the Carpathian mountains. It does not exist in Scandinavia, but is to be seen in Poland, and the Ukraine. It is found at the mouth of the Don, and proba-

[t] Georgi, Description de la Russie, iii. 1533, *sqq.*

[u] Id. ibid, 1607.

bly in Caucasus; it inhabits the Ural mountains near the river of Kama, and from thence the race has been propagated as far as Daouria. In the new world, this animal is found from Canada to Virginia, and even upon the Bahama islands. The *Badger* and some other small animals inhabit equally the northern half of the temperate zone; but the identity of these species is neither established nor disproved in a manner quite satisfactory.

Quadrupeds belonging to the ancient continent.

The quadrupeds which exclusively belong to the one or the other of the two continents, are in general such as are unable to support the cold which prevails beyond the 60th parallel. The *Lemming* however, a species of mouse, which often migrates, in vast numbers, from one country to another, inhabits the whole of the frozen zone of the ancient continent, but has not been discovered in America. The animal named the *Musk*, resides in the mountains of Asia, from Cachemire and the Altäi, to the mouths of the river Amur; it is not spread over any part of the new world. There are still some exceptions less remarkable.

Certain animals appear to be attached to the confines of what may be called the torrid part of the temperate zone. The *Camel* seems to have originally come from Bactriana, or Great Bucharia[x]. It lives in European Turkey, in the Crimea, and amongst the Kirguises and Baschkirs, under the 55th degree of latitude, and in a very rigorous climate[y]. We find it even throughout the whole of Sougaria, in Mongolia, and in the country of the Mantcheoux Tartars, where the winter begins in September and ends in May. The camel does not advance farther than the 28th degree, in China and India. It cannot exist in the peninsula of Hindustan; but in Arabia it has been inured to live nearer the torrid zone.

Camel with two humps.

The *Dromedary* or camel with one hump, well known for its fleetness, appears to have come from Arabia[z], or

Camel with one hump.

[x] Arist. Hist. Anim. cap. I. Plin. viii. 18. Bochart, Hierozoicon, lib. ii. cap. 4. p. 87, 89.

[y] Pallas, Voyages en Russie, ii. 302 *sqq.* iii. 20. *sqq.*

[z] Bochart, i. c.

Africa. It has been brought as far as South China; but it thrives best in Africa, where it is to be met with in Egypt, in Barbary, on the banks of the Senegal and the Gambia, in Nigritia, and even in Guinea and Abyssinia. We had conjectured that it was an inhabitant even of the centre of Africa [a]; the English journals announce, that it was lately observed to the north of the country of the Boushouanas, under the tropic of Capricorn; but the account which they give requires confirmation.

Both kinds of camels appear to be chiefly attached to that long tract of mountainous country, and naked elevated plains, which traverse the whole of the old continent, and on which they find saline plants, such as the *salsola*, the *statice*, the *artemisia*, the cherry of the steppes, and the *Cytisus hirsutus*, which serve for their ordinary food.

The nimble *Chamois* loves the mountains of the temperate zone, the tops of the Pyrenees, the Alps, the Appenines, the Carpathian mountains, Caucasus, and the country of Siberia, to the banks of the Ischim.

The Gazelle, antelope, &c.

The *Antelope saiga*, and the antelope with the goitre, inhabit the upland plains of Tartary; the former is found as far as the 53d parallel. The *Gazelle*, with its mild and brilliant eyes, prefers the more southern countries; a native of Caucasus, along with the chamois, the gazelle extends its range as far as Arabia, and across the whole of Africa to Senegambia. It is to be met with in the southern temperate zone, and in Cafraria, together with a great number of other species of antelope. The race of *antelopes* follows, like the camels, the great upland plains of the old continent. There are species however, which appear to be peculiar to the cold temperate zone.

Jackal.

The *Jackal* lives, according to Zimmermann, in Turkey, in Barbary, in Bengal, and in general in the countries of Asia and Africa situate between the 43d and 8th degrees of northern latitude. But an animal which lives so near

[a] Géographie de toutes les parties du Monde, publiée par Mentelle et Malte-Brun, i. 518.

the line may certainly pass it; the supposed wolves of Congo and of Cafraria appear to us to be jackals.

The *Buffalo*, commonly regarded as originally coming from the torrid zone, has been domesticated, and carried as far north as the 46th degree, both in Europe and Asia. It is probable that the *bonasus* described by Aristotle, and which lived wild in the mountains of Pæonia, a district of Thracia, was a species of buffalo [b]. There are two other species which occupy each a separate tract of country. Buffalo. Grunting ox.

The *Grunting Ox*, or the *Yak*, inhabits the upland plains of Mongolia or Thibet.

The *Buffalo of Cafraria*, appears to be spread over all Africa; for why should we not refer to this species all the ancient accounts [c] of bulls of a monstrous size, carnivorous, and objects of terror both to men and animals, which were alleged to have been seen in Upper Ethiopia, that is, in Sennaar and Abyssinia, and to which Philostorgus gives the name of *bull-elephants?* These accounts have been confirmed by the evidence of modern times [d]. The species with moveable horns, indistinctly noticed by the ancients, appears to have been rediscovered upon the Mozambique coast. It is possible that we shall yet meet with the oxen and buffaloes of the Garamantes, whose horns pointing towards the earth, forced them to move backwards as they fed. Buffalo of Cafraria.

A numerous family of *Apes* gambol in the forests between the tropics, and show rather a dislike to the temperate climates, at least in their wild state. The apes that live out upon the rocks of Gibraltar, have propagated in that situation, but they have degenerated. Quadrupeds of the torrid zone of the old continent.

As the word *ape* has been taken in a very generic acceptation, it is said that this animal, though confined to the torrid zone, is equally to be met with in the two continents; Apes.

[b] Arist. Hist. Anim. ii. cap i. 9. ix. cap. 45. de part. animal, iii. 2.

[c] Agatharcid. ap Phot. Biblioth. cap. 39. Strabo, Geog. xvi. p. 533. edit. Casaub. 1. Plin. viii. 21. (we must distinguish the oxen of India with very large horns, Plin. viii. 45. Ælian, Hist. Anim. xvii. 45.)

[d] Ludolf. Comment. ad Histor. Æthiop. i. cap. 10. iii. cap. 11.

but, if we carefully distinguish the various species, we shall perceive that there are none of them common to both.

Countries of different apes.

There is a very distinct line of demarcation between the country occupied by the *Monkey*, the *Baboon*, the *Mandrill*, the *Jocko*, and the other apes of Africa, and that inhabited by the real *Ourang-outang*, the *Gibbon*, and the *Wouwou*, animals which most nearly resemble the human figure, and which, as they are met with in the islands of Borneo and Java, may have come at first from New Holland or New Guinea. Even in the tribe of *Makis*, there are limits marked to each species: the *Loris* belong to the East Indies; the *Gallagos* to Senegambia; and the *Makis*, properly so called, to Madagascar [c].

Giraffa.

The *Giraffa*, or the *camel leopard*, so remarkable for its height, its swan-like neck, and its gentle manners, seems to belong only to one region of Africa, namely that which extends in length from Cape Guardafui to the Cape of Good Hope, and to which should be joined the mountainous plains, which probably occupy all the interior of southern Africa, between the sources of the Nile and those of the rivers of Congo, Benguela, and Monomotapa.

This region, which is almost unknown, with the exception of the maritime parts, seems to be very prolific in different kinds of animals. Here, two sorts of asses, the

Zebra.

Zebra and the *Quagga*, are to be met with, and the wild boar in his greatest strength; and here also we shall probably find many of our domestic animals in a wild state, as well as on the central plains of Asia. As this region of Africa enjoys but a moderate degree of warmth, the camel leopard appears to be confined to it, less by the climate than by its own extreme timidity. It is seen as far as the twenty-eighth degree south, but only on the eastern coast.

Rhinoceros's with one and with two horns.

The two varieties of the *Rhinoceros* have, each of them, its own country. That with two horns inhabits only South Africa, beginning at Congo and Abyssinia. The other, with one horn, is found in the East Indies, and in China;

[c] Cuvier, Tableau Element. p. 94. *sqq.*

in this latter country the rhinoceros lives to the thirtieth degree north. They have on the other side of the line spread as far as the islands of Sunda. Some accounts would persuade us that the rhinoceros with one horn exists in Monomotapa[f]; but this is probably a distinct species.

The *Hippopotamus* is now confined to Africa; it lives in all the great rivers of that quarter of the world, and is seen in great numbers near the Cape of Good Hope. Hippopotamus.

The *Elephants* of Africa and Asia are of two different races, which have probably not intermixed; for the Asiatic elephant inhabits only India, China, as far as thirty degrees, and some islands to the south-east of Asia, to which he has been transported by man. In Persia and in Arabia, we find no elephants but those which have been brought from other countries; and we know that the animal never propagates in the domestic state. The African elephants do not advance farther north than the 20th degree; from thence to the Cape of Good Hope they are every where met with in great numbers. Elephants of Asia and Africa.

The *Lion*, the powerful and formidable king of quadrupeds, has been stript of a great portion of his dominions; for, in the age of Homer, and even in that of Aristotle, the inhabitants both of Greece and of Asia Minor, were accustomed to fly from his approach[g]. From profane and sacred history, we know that there were lions in Armenia, in Syria, in Palestine, and in Egypt. In none of these countries does the lion now appear. This dreadful animal has been taught to dread the arms of man; he has retired into those countries where there are fewest inhabitants; he roams in the deserts of Arabia, from whence he extends his ravages to the environs of Bagdad. The lion is to be met with, according to Zimmerman, in the mountains of Hindostan, and upon the coast of Malabar, upon the Gauts of India, and even in the islands of The lion.

[f] Thomann's Voyage and Biography, in German p. 118.
[g] Herod. vii. c. 126. Arist. Hist. Anim. vi. c. 31.

Sunda, and the kingdom of Siam. This appears to be extremely improbable. Africa always was, and still is, the country most celebrated for an abundant breed of lions, notwithstanding the numbers carried away by the Romans for their sanguinary sports. The lions which roam in the elevated but burning plains, beyond Mount Atlas, are the most distinguished for strength and courage.

The tiger. The *Tiger*, less extensively distributed than the lion, approaches nearer the pole, if it be true that Tournefort saw some of the species upon Mount Ararat. The Russian writers allege, that a stray tiger is occasionally observed roaming as far as Mongolia, and on the banks of the Ischym, in Siberia [h]. They are found also in eastern Persia, and in China; but the climates in which they attain the greatest size, and display most ferocity, are those of Bengal, the Deccan, Malabar, Siam, Pegu, Ceylon, and Sumatra. It is in these countries that the *royal tiger*, a fit favourite of oriental despots, gets glutted with the blood of the slaves who are consigned to his fury.

Panther. Leopard. Africa contains no genuine tigers; but, by way of compensation, it has *Panthers* and *Leopards*, two species that are sensibly distinguished only by their spots, these being more beautiful and more perfectly rounded in the leopard, which chiefly inhabits Guinea and Senegambia.

The ounce. The *Ounce*, which differs from the panther in the grey colour of its hide, and the superior mildness of its nature, is more widely distributed, as it is found throughout the whole of Barbary, in Arabia, in Tartary, and China, and sometimes makes its appearance near Kutznesk in Siberia.

Inference respecting the animals of the ancient continent. From this sketch of the geographical distribution of animals peculiar to the ancient continent, the following general inference appears deducible, viz. that the *interior of Asia, and that of Africa, have been each of them the native region of a certain number of species of animals.* The tiger, the Indian elephant, the camel with two humps, the

[h] Georgi, Description de la Russie, iii. 1519.

wild sheep, the *Koulan* or wild ass, the *Dchiggetai* or horse ass, the grunting ox, the elk, and the musk, are the animals peculiar to the central upland plains of Asia. Those which are characteristic of the upland eastern plains of Africa, are the lion, the African elephant, the dromedary, the buffalo of Cafraria, the zebra, the quagga, and monkeys. We cannot help thinking, although on evidence which we admit to be weaker, that the northern upland-plain of Africa, or Mount Atlas, the western upland plain of Asia, or Taurus, and the centre of Europe, or the Alps, have equally had their indigenous races of animals. If the two great masses of the old continent have produced each of them its own races of animals, why should not the new world have also races of its own? Why should the majestic chain of the Cordilleras of Mexico and of Peru, have been more excluded from the general action of vital energy than the central upland plains of Asia and Africa? Quadrupeds of the new world.

Nothing can be more natural than to suppose that the vast and isolated continent of America had also its peculiar creation. The very few animals which were able to pass from the one continent to the other by the north, could scarcely have traversed the very hot climates in the interior of America. South America at least, then, would have remained wholly desert, had not nature, which leaves no spot unpeopled, furnished the new continent with species of animals entirely unknown to the ancient world.

Amongst the animals which peculiarly belong to North America, we think, may be reckoned the great elk, named the *Moose-deer*, as well as the great stag of those countries; species which, to the eye of a mere naturalist, would appear only as varieties of families found in the ancient continent, but which physical geography pronounces to be originally different, by shewing the extreme improbability of their supposed passage from Asia to the north-west coasts of America. The bears, the lynxes, the ounces of the United States, are probably as different from the animals of the same name in the old continent, as the squirrels and hares are upon which they feed. Quadrupeds of North America.

Bison. The *Bisons*, or humped bulls, are the largest quadrupeds in the new world: They roam in great herds from Hudson's Bay through the whole of Canada, to the western territory of the United States, to Louisiana, to New Mexico, and as far as the shores of the Gulf of California; that is, from the 52° to the 33° of north latitude. They differ from the *zebus* of India, and from the *urus* of Europe: but the thick wool which clothes their back and neck, as well as the beard that covers their chin, remind us, it must be confessed, of the *bison*, described by the ancients as an animal inhabiting Scythia [i].

Musk ox. Mention is made of a *Musk ox*, which inhabits the extremities of America, between the Welcome, Baffin's Bay, and the Copper River. According to other accounts, it wanders as far as towards the Pacific Ocean [k]. It is alleged to be a species of buffalo, but the accounts are still very vague as to this point. The Mexican stag is to be met with in both Americas, so that we cannot ascertain its native country; but the animal resembling a large sheep, which has been observed to the north of California, appears to be different from the analogous species which browse in Peru.

Quadrupeds indigenous to South America. The *Yaguar*, the tiger of the new world, resembles the ounce in strength, and the panther in skin. Zimmermann proves, from the narratives of modern travellers, that there are of the species of yaguars some which equal the tiger in size.—The *Puma*, or the *Couguar*, which has been called the American lion, has a body more nearly resembling the wolf, and a head like that of the leopard of Guinea. These are two kinds quite unknown to the old world. The yaguars supposed to have been seen in Mexico, were probably either ounces or lynxes. It is equally doubtful whether this animal has advanced as far as the cold country of

[i] "Villosi *terga* bisontes." Sen. Hippol. v. 64.

[k] P. Marco de Niza, quoted by Zimmermann, Almanach de Voyages, 1806, p. 73.

Patagonia. The *couguar* is not distributed farther than the 45° of south latitude.

The *Lama* or *Guanaco*, which has been improperly named the camel of the new world; and the *Paco*, which in its domestic state is called *bicunua*, or vigonia, or Peruvian sheep, inhabit Chili or Peru, to the 10° south latitude; they are distributed neither in the plains of Tucuman, nor in those of Paraguay [1]. Lama.

The *Tapir* is the largest quadruped of South America, although it is only the height of a cow; the armadillo, the tajassou, the idle aï, or sloth, the *Fourmilier*, or ant-eater, the *Tamanoir*, the different *Agoutis* and *Coatis*, species, all of which acknowledge South America as the place of their nativity, do not in general spread beyond the tropic. The tajassou, however, according to some accounts, is found in Chili. The small long-tailed apes, the *Sapajous* or *Marmosets*, the *Tamarins*, the *sagouins*, and other similar species, are very numerous, very various, and very pretty over all the torrid zone of America; they essentially differ from the apes of Africa and Asia. Tapir. The Ant-eater, Agoutis, &c. Marmosets, Sagouins, &c.

On the confines of the temperate zone, we obscrve stags of different kinds, the beaver of Chili, various *Caviais*, similar to hares, and, according to Molina, the horse with cloven feet. The species which exclusively belong to the New Continent, are, as we have seen, very numerous; but they are of a much smaller size than the analogous species which live under the same latitudes in the ancient world. Physical geography informs us of the causes of this peculiarity. Do we not know the peculiar configuration of the American continent? Mountains cold, and partly barren, are immediately succeeded by marshy forests, and plains continually inundated. The torrid zone in America affords but a small extent of land; the temperate zone of the North is encroached on by cold marshes; in that of the South, the continent tapers almost into a point. Thus, Small size of animals in America.

[1] Helms, Voyage de Buenos-Ayres à Lima. Azara, Quadrupedes de Paraguay.

throughout the whole of this continent, the larger species of animals are either strangers to the climate, or have not room for the full development of their energies. On the other hand, imported animals which agree with the climate of America, lose nothing of their size, their beauty, or their strength. The horse and the ox have not in the least degenerated in the extensive pastures of Paraguay. If the human race appears to have undergone deterioration in America, this should be ascribed rather to political than to physical causes.

If reptiles and insects abound in America, if they there attain a larger size than any where else, it is only when considered relatively to the known regions of Africa. These regions, peopled from time immemorial, have seen their primitive animals fly before the face of man; but who knows whether the unexplored interior of that continent does not contain extensive marshes, as thickly peopled with reptiles and insects as the coasts of Guyana? Does not, moreover, the Delta of the Ganges swarm with serpents of enormous size?

Character of the zoology of South America.

The distinctive character of South American zoology consists then, principally, in the difference of species, a difference which proves how little intercourse this great peninsula has had with the rest of the world; it has not received any species even from North America, while the latter country has beheld the number of its animals augmented by accessions from those of South America.

Quadrupeds of the Oceanic Countries.

We have still to consider another province of the animal kingdom, a province hitherto imperfectly explored, but certainly very distinct from those which we have already examined. The islands to the South East of Asia, as well as the great island of New Holland, occupy a position very similar to that of South America. In them, therefore, should be the cradles of races of animals very different from those of the two Continents. These races, however, are far from being plentifully distributed in the remainder of that vast archipelago, which is placed in the centre of the great ocean. We do not find there the *Ornithorinques*, nor the *Wombat*,

nor the *Opossum*, nor the *Kangaroos*, animals peculiar to New Holland. We must, however, remark that these species resemble the didelphes which are common in the neighbouring islands of Asia, that *opossums* are met with in the Moluccas, that in Java, there are *Kangaroo-phalanders*, and that, if the flying phalanger resides in New Holland, the white phalanger inhabits the island of Amboyna. Labillardiere found the lizard of Amboyna in the Friendly Islands. We may add, that the *Cassiowary* belongs equally to the Molucca islands, to Java, and New Holland; and, without waiting till it be discovered whether there exist in that great island, the *Babiroussa*, or stag hog, the *Cervus axis*, the *Ourang-outang*, and other mammiferi of Borneo, the Philippines, and the Moluccas, we may consider the fifth part of the globe, or the Oceanic countries to the south east of the Chinese sea, as the native region of an assemblage of animal tribes, of which future discoveries shall increase the number and unfold the relations.

Kangaroos, Wombats.

Stag Hog, Ourang-outang, &c.

These general views of the geographical distribution of animals, however imperfect they may be, may assist our readers in classifying the numerous details of our subsequent and particular descriptions of regions and countries.

BOOK XXII.

Continuation of the Theory of Geography. Of the Earth, considered as the abode of Organic Beings.

SECTION III.

OF MAN, PHYSICALLY CONSIDERED.

Dignity of man.

THE physical organization of man, while it subjects him to those laws of generation, growth and dissolution, which extend to all orders of living nature, bears at the same time, in each of its parts, and as a whole, a character so peculiar, so extraordinary, and so sublime, that it is impossible to suppose even the most distant relationship between the brutes, which do nothing but feed and propagate on the surface of the earth, and him who is born to exercise dominion over them. That upright and elevated port, which indicates both dignity and courage; those hands, the trusty instruments of our will, the dexterous performers of the most magnificent, as well as the most useful works; those eyes, uplifted from the dust, whose intelligent glance can survey the immensity of the heavens; those organs, which enable us to express thought by articulate sounds of endless variety; the admirable union of strength and suppleness in all our members; finally, the harmony and perfectibility of all our senses, assign to us the first rank amongst living beings, and give us both the right to claim and the power to hold the empire of the earth.

Anatomy and physiology have placed these truths beyond the reach of dispute[a]. Those naturalists who have pretended to confound the human species with that of

[a] See Cuvier, Leçons d'Anatomie comparée, etc.

monkeys, notwithstanding the essential difference in the feet, in the organs of speech, and the notes of the voice, appear to recognize no fixed principle whatever in their classification of the species of animals.

Effects of our organization.

Even the apparent disadvantages of our organization powerfully accelerate the improvement and the happiness of human existence. Endowed with the strength of the lion, mailed like the elephant, or clothed with a skin impenetrable to cold and humidity, we should perhaps have remained benumbed in stupid indolence, and ignorant of all the arts of life. The extreme feebleness of the human frame at the moment of its birth, the slowness of its growth, the multiplicity of its wants, all those infirmities, all those ills which nature has appointed as our attendants in the journey of life, serve as so many spurs to quicken our dormant faculties, and as so many bonds by which man is knit together with man. Hence the origin of civil society. From the long lasting helplessness of infancy, arises the endearing relation of parents and children; from this relation springs the permanent nature of the conjugal union. The union of men in families is followed by the formation of tribes and nations. It is by uniting with his fellows, and living together under one common law, that man has, as it were, created man; it is by forming a correct estimate of his weakness, and by inventing instruments to assist it, that he has obtained the mastery and the management of the powers of nature; he has felt his penury, and the stimulus of this uneasy feeling has procured for him his true wealth.

Unity of the human kind.

This animal, so distinguished from all others, forms in the scale of being an insulated *order*, which contains no more than one genus and one *species*; for we understand by species, a certain number of organic beings which propagate each other, and which differ only in qualities that are variable and distinct from the characters marking the species. Now, all the nations and tribes of human beings of which we have any knowledge, produce, by sexual intercourse, individuals that are prolific, or capable of producing other human beings in their turn. And, on the

other hand, the differences observable in these tribes are confined to qualities which we still see every day varying, according to the nature of the food which is eaten, and from the influence of climate and disease [b].

The first of these assertions does not require illustration. The numerous classes of *mongrels* and *mulattoes* produced by the union of different human tribes, are sufficiently known. As to the second point, we observe that the differences by which the varieties or tribes of the species are distinguished, relate to the *stature*, or the *physiognomy*, or the *colour* of the skin, or the *nature of the hair*, or, lastly, to the form of the *skull* or *cranium*.

Differences of the varieties or tribes of the human species.

Every person knows that a simple mode of life, abundance of nutritious food, and a salubrious atmosphere, give to all organic beings large and graceful forms. The example of the Laplanders and Hungarians, whose language indicates their common origin, and who differ extremely in stature and physiognomy, sufficiently proves that the beauty of the same race varies with the climate and the qualities of the country. The Germans of Tacitus, those Patagonians of Europe, are no longer found in civilized and cultivated Germany, whilst the Hollander, in the interior of the colony of the Cape, has become almost a giant [c]. How many contrasts do we not meet with in a single nation, and at inconsiderable distances? The female peasants of Westrogothia are uncommonly pretty, and those of Dalecarlia are in general ugly, although both provinces occupy the centre of the real country of the Goths [d]. Violent passions, the yoke of superstition, dull or cheerful occupations, habits of activity or indolence, stamp a permanent character on the physiognomy of whole nations.

Causes of the difference of stature.

Several differences of physiognomy are, partly at least, the effect of art. Numerous eye-witnesses concur in assur-

Artificial physiognomy.

[b] Blumenbach, De Varietate nativa generis humani.

[c] Barrow's Travels in Africa. Sparmann, Thunberg, &c.

[d] Arendt, Voyage en Suède. Thunberg, i. 234, &c.

ing us, that the Negroes[e], the inhabitants of Brazil and the Caribbees[f], the people of Sumatra, and those of the Society Islands[g], depress and flatten, with great care, the nose of new-born infants, a practice which indeed could not have given rise to such a hereditary configuration, but which contributes to render the exceptions extremely rare.

Causes of variety of colour.

Variety of colour seems equally to depend upon external circumstances. In the same nation we often observe individuals of extremely different complexions. While the Moorish ladies, shut up in their houses, and scarcely ever exposed to the sun, have complexions of a dazzling whiteness, the women of the lower ranks, even in their youth, acquire a colour approaching to that of soot[h]. The Abyssinian mountaineers are as fair as the Spaniards or the Neapolitans, whilst the inhabitants of the plains are almost black[i]. Amongst the Creoles, or Europeans born in India, the women are distinguished from their sisters born in Europe, by the sprightliness of their look, and the ebony colour of their locks[k]. The cause of colour exists in the mucous and reticular texture, [*rete mucosum*] which is immediately under the epidermis. If, from the influence of extreme heat, or from some other local cause, there is an excess of carbon in the animal economy, it is thrown out along with the hydrogen, by the action of the blood-vessels of the cuticle; but having been precipitated by the contact of the atmospheric air, it becomes fixed in the *rete mucosum*. The application of these principles, which we owe to modern chemistry, enables us to explain why the skin of white men

[e] Report of the Committee for the consideration of the Slave Trade, 1789. fol. p. 1. c. 1.

[f] Lery, Voyage au Brésil, p. m. 98. 365. Delaborde, Relation des Caraibes, Paris, 1764. p. 129.

[g] Marsden's History of Sumatra, p. 38. Forster, Bemerkungen, &c. p. 433, and 516.

[h] Poiret, Voyage en Barbarie, i. 31.

[i] Bruns, Afrika, ii. 119.

[k] Hawkesworth's Collection of Voyages, iii. p. 374.

blackens in certain maladies, whilst negroes, in the same circumstances, grow white, or rather yellow. Both phenomena indicate a derangement in the secretions. But we will not conceal the only difficulty with which this explanation is attended. If the negroes descend from a race originally white, millions of years must have elapsed before the repeated action of the climate could have rendered their black colour hereditary. But, geological monuments seem to shew that the antiquity of the human species falls greatly short of such a period. "Either then," will some philosophers say, "either allow, for the action of the causes which have formed the various races of men, an immense series of ages, or admit that these races, if they have existed only for 5000 or 6000 years, must have sprung from different pairs that were originally stamped with all the characters of their descendants." It is by a course of observations upon the negroes transported from Nova Scotia, and other countries, that our remote posterity shall be enabled to solve this difficulty.

Difficulty on the subject of colour.

The numerous varieties of hair equally depend upon the secretions of the elementary substances, of which the body is composed. But here the facts appear contradictory. Among the civilized nations of Europe, the hair invariably becomes of a lighter colour, as we advance towards the north. Amongst the barbarous nations of Africa, Asia, and America, the same colour of hair is found in climates completely different. While the dark-haired Italian, and the Scandinavian with his flaxen locks, although belonging to the same variety of the human species, exhibit the effects of the action of climate, the Laplanders and the Samoides have hair as black and as rough as the inhabitants of Mongul, Thibet, and China, a race with which, for other reasons, we must assign them a common origin. All the negro tribes have woolly hair, even the Jalops, who have theirs a little longer and less curled [1].

Variety of hair.

[1] Bruns. Afrika, v. 69.

Cause with the Europeans.

It does not appear that the hair of the Americans presents any shades of difference compared to those which we observe in European nations. We might attempt to explain this fact, by supposing that the nations of the European race, having separated at an early period, occupied countries extremely diversified in regard to climate, and pursued very different modes of living, whilst the Mongul or negro tribes must have multiplied at first in a physical region, whence they spread themselves, perfectly formed, into the countries which they now inhabit. But this explanation, not admitting of being applied to the Americans, cannot entirely solve the difficulty. The nature of the hair still remains one of the most specious arguments in favour of the system which supposes a plurality of species of men.

Influence of civilization.

We observe, however, that in the European race, the colour of the hair appears to change with the civilization, or rather with the degeneracy of nations. The fair-haired race, which, in the age of Homer, furnished Greece with kings and heroes, still existed in the days of Tacitus in Belgic Gaul and in Germany; but now it appears to have become extinct in the cities of the north. Is it the fact that spicy food, beverage abounding in alcohol, luxury, and voluptuousness, gradually change the physical constitution of these nations?

Varieties of the form of the cranium.

The varieties in *the form of the cranium* or skull, seem to be of more importance than all those we have examined; at the same time, since the researches of Mr. Gall [m] have demonstrated, that the external configuration of the cranium depends upon the form of the brain, we can scarcely consider diversities in a substance which is soft, and susceptible of every form, as presenting a character unequivocally marking a diversity of species.

General cause.

The form of the cranium appears to us to depend as much as the physiognomy upon the moral character of the

[m] Gall and Spurzheim. Anatomie du cerveaux, &c. &c. avec fig. Chez. Schoell.

individuals. Though it is impossible to assign to every passion, and to every faculty, a separate organ in the brain, it is certain that men of great talents, and of strong passions, have the head more varied with bumps and protuberances than the multitude. Another fact is, that in those nations, the individuals of which most nearly resemble each other in character, and which have been least mixed with other tribes, the skulls appear to have been cast in one common national mould. When we see the head of one Hindoo, we see the heads of the whole nation[n]: on the contrary, in Europe, where the characters of individuals vary extremely, we find skulls of every form, even the most remote from what we reckon the regular shape.

Artificial cause.

Independently of this general cause, to which should be added the effects of food and climate, the form of the head is frequently modified by artificial means. A pressure continually applied for a great number of years, much more frequently imparts to the smooth bones of the head a peculiar configuration, which becomes even national at last. This effect may be produced by the manner in which some nations place their children in the cradle, or by manual compression, long and carefully applied. Vesale relates, that in his time almost all the Germans had the head flattened behind, and enlarged at the sides, because they were always laid on their backs whilst in the cradle[o]. The Belgians, on the contrary, who were accustomed in infancy to sleep on their sides, were remarked for the length of their head. The American savages, from south Carolina to New Mexico, have all of them the skull depressed, because they lay their children in the cradle in such a position that the crown of the head, which is placed upon a bag filled with sand, supports almost the whole weight of the body[p].

[n] Comp. the fine work, "Les Hindous," par M. S Lynn

[o] Vesale, quoted by Blumenbach, § 63

[p] Adair's History of the North American Indians, p. 9.

A practice prevalent in ancient as well as modern times, in our climates, and in the most distant countries, is to bring the head of the new-born infant to a national form by means of bandages, different sorts of instruments, or even the simple pressure of the hands. This custom obtained formerly, and still continues, among the inhabitants of several parts of Germany [q]; among the Belgians [r]; the French [s]; in several districts of Italy; among the Islanders of the Grecian Archipelago [t]; the Turks; the ancient Sigyni, and the Macrocephali of the Euxine Sea [u]; it prevails to this day among the inhabitants of Sumatra and Nicobar [x]; and particularly amongst the different nations of America, such as the people of Nootka Sound [y]; the Chactas; the native inhabitants of Georgia; the Waxsaws of Carolina; the Caribbees; the Peruvians [z]; the Omagnas [a]; together with the negroes of the Antilles [b]. This practice was forbidden in Spanish America, by the decree of a national council [c]. We are in possession of the most exact descriptions of the means which these savages employ to give the heads of their children, by an uniform pressure, the configuration they desire [d]. This fact being established by so many unexceptionable witnesses, all which remains now is to ascertain whether the forms of the cranium, obtained by these means, become, after a long series

People who put the head out of form.

[q] J. Chr. Gottl. Ackermann, dans Neues Magasin fur Aerzte, de Baldinger, vol. ii. p. 5, 6.

[r] Spigel, de Hum. Corp, Fabricâ, p. 17.

[s] Andry, Orthopedie, vol. ii. p. 3.

[t] Philites, a physician of Epirus, quoted by Blumenbach. Strabon, l. xi. p. 358. Hipp. de Ærib. aq. et loc.

[u] Marsden's History of Sumatra, p. 38.

[x] Nic. Fontana, in the Asiatic Researches, vol. iii. p. 151.

[y] Meares's Voyages, p. 349.

[z] Oviedo, Histoire Gener. de las Indians. Torquemada, Monarchia Indiana, vol. iii. Ulloa, Relacion del Viage, vol. ii. p. 533.

[a] La Condamine, Mem. de l'Academie des Sciennes, 1745, p. 427.

[b] Thibault de Chanvalon, Voyage à la Martinique, p. 39.

[c] Jos. Saenz de Aguire, Collectio Maxima Conciliorum Omnium Hispaniæ et Novi Orbis, vol. vi. p. 201.

[d] Journal de Physique, d'Aout. 1791, p. 32.

If these shapes become hereditary?

of generations, natural and hereditary. Hippocrates, in his treatise on air, waters, and situations, mentions particularly the *Macrocephali*, a nation in the vicinity of the Pontus Euxinus. According to him, no other people had the head shaped like theirs; and this conformation originally resulted from a particular practice. The Macrocephali regarded a long head as the index and symbol of courage; in conformity with this opinion, they moulded the heads of their infants at birth, and endeavoured, by various contrivances, to give them length at the expense of breadth. This form at last became natural, and no care was required to produce it.

Varieties in the different parts of the body.

There are also in the form of the human body, other diversities which appear peculiar to nations, and perhaps to different varieties of the human species. It is alleged that several savage tribes have moveable ears; but it has been probably under the impulse of a satirical spirit, that some authors have assured us, that the ancient Batavians had ears singularly deformed, and that, amongst the inhabitants of Biscay, these organs are of an unusual length. The pendent breasts of the negresses are occasioned by the practice of suckling their infants suspended from their backs. The fulness of this part seems to be the effect of a warm and humid climate.

We shall notice elsewhere the deformity of the Boschman women in South Africa. Amongst the tribes of the South Sea, or Great Eastern Ocean, the chiefs owe their swollen legs to their indolence and manner of sitting. Perhaps also the *elephantiasis*, a malady frequent in Africa, Arabia, and Indostan[e], extends over the Oceanic countries. The crooked legs of the negroes, which had been observed by the ancients[f], appear equally common amongst the *Mongol nations*[g]. This deformity has been attributed, either to their being prematurely accustomed to the saddle, or to the posture in which they are placed, during the pe-

[e] Allard, Histoire d'une Maladie Particuliere au Systeme Lymphatique.
[f] Arist. Problem v. 11, &c.
[g] Pallas, sur les Nations Mongoles, vol. i. p. 98.

riod of lactation, fastened to the back of the mother, and clinging to her forcibly with their knees.

There are more important varieties in the shape and proportion of the lower limbs, and which are peculiar to the nation or the tribe. The savages of New Holland have legs extremely long and slender [h]. It is not true that this peculiarity occurs amongst the Hindoos, as we are told by an observer unworthy of credit [i]. But it appears certain that the Mongols and Americans have their legs and thighs too short in proportion to the rest of the body. Some nations have small hands and feet. The Hindoo sabres, frequently brought into England, are too small in the hilt to be wielded by most Europeans [k]. We might refer also to the Chinese, the Kamchadales, the Esquimaux, the Peruvians, the Hottentots, and the inhabitants of New Holland [l]. Variety in the proportion of feet and arms.

Nations differ very much in the degree of strength with which they are endowed. The interesting experiments of Peron and Regnier, have proved that savage, or half civilized nations, yield to the Europeans in all kinds of active force; but we have no doubt that they possess, in a more eminent degree, that *passive force* which resists the inclemency of the seasons. Different degrees of strength.

After summing up all the observations made by travellers, the celebrated Blumenbach reduces all the varieties of the human species to *five principal types or models*, on which a deliberate and minute examination has enabled us to make only a few slight modifications. Five principal varieties.

The first variety occupies the central parts of the old continent, namely, Western Asia, Eastern and Northern Africa, Hindostan, and Europe. Its characters are, the colour of the skin more or less white or brown; the cheeks Central variety of the old continent.

[h] Péron, Voyages aux terres Australes, Atlas, pl. xx.

[i] La Boullaye le Gouz, Voyages et Observ. p. 153. Comp. Solvyns, l. c.

[k] Hodge's Travels in India, p. 3.

[l] De la Barbinais, Voyage autour du Monde, vol. ii. p. 62. Dampier's Continuation of Voyage round the World, p. 100. Wales Philosoph. Transact. vol. lx. p. 109; and Curtis, ibid. vol lxiv. p. 383. Watkin Tench's Account of the Settlement of Port Jackson, p. 179.

tinged with red; long hair, either brown or fair; the head almost spherical, the face oval and narrow; the features moderately marked; the forehead smooth; the nose slightly arched; the mouth small; the front teeth perpendicularly placed in the two jaws; the lips, particularly the lower one, slightly pouting; the chin full and round. The regularity of the features of such a countenance, which is that of the European, causes it to be generally considered as the most handsome and agreeable. The features of the Hindoo, the Abyssinian, and the Breber, or inhabitant of Mount Atlas, do not essentially differ from those of the European, except in the colour of the skin, which is darkened from the effects of the climate, and which, moreover, amongst the Hindoos, and even the Abyssinians, acquires a very fair tint in the mountainous provinces. Blumenbach designates this race the *Caucasian;* but by bestowing this name he invades the province of civil history, which assigns us no reason for believing the people of Caucasus to be more ancient than those of Mount Atlas or the Alps. Neither physiology, nor physical geography, furnish the least proof, that this variety of the human species has had a common origin; it has formed itself wherever there existed the physical causes on which it depends.

Eastern variety of the old continent.

The second variety is that which was at first erroneously designated under the appellation of *Tartar*, though the Tartars, properly so called, do not belong to it. We shall call it, the *Eastern Race*, or *Variety of the Ancient Continent.* The following is its character; yellow colour; hair black, stiff, straight, and not very thick; the head almost quadrangular; the face large, flat, and depressed; the features indistinctly marked, and, as it were, blended together; the space between the eyebrows large and smooth; the nose small and flat; the cheeks round and prominent; the opening of the eyelids narrow and linear; the chin pointed.

This variety comprises all the Asiatics to the east of the Ganges, and of Mount Belour, except the Malays of the extremity of the peninsula beyond the Ganges. In Eu-

rope this variety is found, according to Blumenbach, amongst the Laplanders and the Finns; and in America, amongst the Esquimaux, from Behrings Straits to Greenland. But we are convinced that the Finlanders, descendants of the ancient Scythians of Europe, should be classed with the first variety, of which they form a very ancient subdivision, having mixed with the Celts and Basques, as will be shewn in the description of Europe.

The Eastern race of the old continent, bounded by the limits that we have just now traced, presents a remarkable identity of tint, physiognomy, form of the skull, and even of language, as we shall see in the sequel.

The American variety resembles, in several points, that which we have been describing. Its principal characters are, the copper colour; hair black, straight, stiff, and thin; forehead short; eyes sunk in; the nose almost flattened, and yet somewhat projecting; the cheek bones in general prominent; the face large, without being flat or depressed. The features, viewed in profile, appear very marked, and of a bold outline. The form of the forehead, and the crown, is often the effect of art. American variety.

This variety comprehends all America, except the northern extremities, inhabited by the Esquimaux. It appears to be composed of several branches, which differ considerably; the complexion, which is white or fair amongst the Kristinaux, becomes almost black among the Brazilians; the features and the skull are sometimes flattened, and sometimes lengthened. All these tribes have a beard [m], but it is weak; there are some who, like the Mongol and Malay nations, pluck it out by the root. The opinion that the American tribes were destitute of beards, owes its origin to De Paw. Robertson the historian, an author still more worthy of credit, has said, that all the Americans have the same cast of countenance: to such a degree have the truths of physical geography been overlooked or disregarded by those who have undertaken to write the history of man.

[m] Blumenbach, Gottingen Magazine, &c. &c.

Variety of the Oceanic countries.

We shall now return to the East, in order to consider the fourth variety of the human species, that of the Oceanic countries, or fifth part of the world, designated by Blumenbach under the too arbitrary name of the *Malay race*. The following are its still very uncertain characters,—a tawny colour; the hair black, soft, thick, abundant, and curled; the head slightly shrunk in; the forehead a little bulging out; the nose thick, wide, and flattened; the mouth large; the upper jaw a little projecting; the features viewed in profile, appear marked and distinct.

This variety comprehends the islanders of the Pacific Ocean, the inhabitants of the Marian, Philippine, Molucca, Sunda Islands, and the indigenous tribes of the peninsula of Malacca, most of the inhabitants of New Holland, and those of New Zealand, and perhaps even some of the nations of Madagascar. But how difficult is it to determine any thing concerning nations so imperfectly known, and which appear to include tribes of different origins! The immortal Quiros, who first discovered the Society Islands, carefully observed the disparity which exists between their inhabitants. He says that some resemble the Whites, others the Mulattoes, and even the Negroes[n]. Modern voyagers have compared the reigning cast in the island of Otaheite, to the Europeans of the south, and the people to the Mulattoes[o]. The very great extent to which the Malay language prevails, and which at first leads us to suppose the identity of these nations, could be the consequence only of ancient migrations and conquests. At the same time, it is proper to state, that the savages of New South Wales, who speak a language different from the Malay, exhibit, notwithstanding, the leading physical characters of the last mentioned variety.

Negro variety.

The fifth grand division of the human race, or the *Negro variety*, is attended by no circumstances of a doubtful

[n] Quiros, in Dalrymple's Collection of Voyages to the Southern Pacific Ocean, vol. i. p. 161.

[o] Bougainville, Voyage autour du Monde, p. 211.

nature. The characters are, colour black; hair black and woolly; head narrow, and compressed on each side; forehead very convex, and arched; the cheek bones projecting; the eyes even with the forehead; the nose large, and almost confounded with the upper jaw, which is carried forward; the border of the gums narrow and elongated; the upper front teeth, or incisores, obliquely placed; the lips, particularly the upper, very thick; the chin drawn in; the legs in general crooked. This variety, which is spread over all Western and Southern Africa, is found also upon the coasts of Madagascar, probably upon those of the north-west, and of New Holland, in the great islands of Van Dieman's Land, in New Caledonia, and New Guinea. It is even supposed that it anciently existed in the Philippine islands, in Borneo, Java, and Sumatra. The *Harafloras*, who still inhabit the interior of some of these islands, are Negroes; so also are the natives of the islands of Andaman. Thus all the regions of the torrid zone, with the exception of America, have produced Negro tribes;—a manifest proof of the influence of climate upon the varieties of the species. But when we observe the differences between a real Negro, with a complexion of jet, and woolly and crisped hair; a Caffre, with a yellow copper complexion, and long woolly hair; a native of Van Dieman's land; a New Caledonian; a Papous, or New Guinea man, of the colour of soot, with frizzled locks,—we remain uncertain whether these three races, separated besides by seas and mountains, are each of them the original inhabitants of their present abode, or whether they have all descended from a common stock.

Three subvarieties of Negroes.

The Hottentots form another remarkable exception: the shape of their skull is that of the Malay race; they have the complexion and the thin beards of the Mongol variety, but their woolly hair resembles that of the Negroes.

Hottentots.

Such are the principal varieties of the human species, spread over the surface of the globe. The ancients erroneously imagined that the torrid zone, scorched by the rays

Geographical extension of the human race

of a vertical sun, cut off all communication between the inhabitants of the two temperate zones. This opinion, which contracted the boundaries of the universe, has vanished away before the discoveries of Columbus, of Gama, and of Cook. Navigators have found inhabitants in the most sultry climates, and in the neighbourhood of the poles, upon the most inaccessible coasts, and even on islands that a boundless ocean seemed to separate from the rest of the world. The islands of Spitzbergen and of Nova Zembla, to the north; Sandwich Isle, the islands of Falkland, and of Kerguelen, to the south,—are the only countries of considerable extent, which have been found entirely destitute of human inhabitants. Man, therefore, has the whole earth as his abode. He can live in every climate, and his habitations reach to the remotest confines of animated nature. The Esquimaux of Greenland dwell as far north as the 80th degree. In the other hemisphere, the bleak and barren Terra del Fuego supports the wretched Petcheres. The New World, then, though in general thinly peopled, is still inhabited from one extremity to the other. In the old continent, the habitations of man form a collected whole, which is broken in upon only by some sandy tracts; and in the midst even of these deserts, man has peopled the *Oasis*, those verdant islands scattered over an ocean of sand.

Heat and cold supported by man.

The human body supports, upon the banks of the Senegal, a degree of heat which causes spirits of wine to boil. In the north-east of Asia, it resists cold which freezes mercury. The experiments of Fordyce, Boerhaave, and Tillet, prove that man is more capable than most animals of supporting a very great degree of heat. We have no doubt that our body would resist extreme cold equally well, provided that it retained the power of moving. As the intensity of the cold should scarcely increase beyond the 78th or 80th degree, it is probable that man could sail under the poles as well as under the equator, if he were not arrested by the ice.

The power which man possesses of speedily accommodat-

ing himself to every climate, appears to spring from the same cause which renders his health less sound and less steady than that of other animals. It is to the superior affinity of the component particles of their bodies to inert matter, that animals are indebted for those instincts of which we are destitute. Our senses, on the contrary, are not so poignant, our body is not so susceptible of impression, the impulse of our passions is not so ungovernable, because the whole of our organization is more subtile, more delicate, and, if we may say so, more intellectual. The instability of health, and the uncertain duration of life, are the natural consequences of this delicate mobility of our organs. It is owing, however, to this same mobility, that our organs obey with ease and promptitude the volitions of the soul. A firm determination not to be overcome by a distemper, but to bear up against it, is, in the opinion of physicians, one of the most potent medicines, whilst an apprehensive and desponding imagination, is sure to aggravate the slightest indisposition. And thus it is that our bodily frame, in order to be fortified against the influence of a new climate, only waits for the orders of the mind, to which it serves as an organ. Under every climate, the nerves, the muscles, and the vessels, by stretching or relaxing, by dilating or contracting, soon acquire the state which is habitually suited to the degree of heat or cold that the body experiences.

Power of supporting different climates.

It is commonly said, that the sum total of men living upon the earth may amount to a *milliard*, or one thousand millions. But all the calculations which have been made upon this subject are chimerical. It is impossible to state any which shall even approximate to truth. Asia, it has been said, contains five hundred millions of inhabitants; but it has been only by proceeding upon the most exaggerated data for each of the countries which compose this quarter of the world, that this sum total has been arrived at. The truth is, we have no greater reason for giving to Asia 500 millions than for giving it 250. Among the different accounts respecting China, how shall we hit upon

Sum total of the human race.

Population of Asia.

the true one? Has that country 27 millions of inhabitants, according to Sonnerat? or 55 millions, according to the extract from the official Gazette of Pekin? or 70 millions, according to the Russians? or 100 millions, as De Guignes believed? or 19,662,000, as M. Busching informs us? or 200 millions, agreeably to the statement of the Missionaries? or, finally, 333 millions, as a Chinese mandarin, perfectly veracious no doubt, assured Lord Macartney? This single example may suffice to convince the judicious reader, that all this parade of figures, is founded only upon vague conjectures. We have endeavoured to compute the population of Asia, by collating the accounts of modern travellers. We affirm nothing: we merely say that it appears to us that we cannot assign to Asia more than from 320 to 340 millions of inhabitants.

Of the Oceanic division.

The *Oceanic* division of the earth, or that collection of large and small islands to the south-east of Asia, contains vast spaces almost entirely unknown. Carrying partial computations as far as possible, we shall find, from Sumatra to Easter Island, and from Manilla to New Zealand, only about 20 millions of inhabitants.

Of Africa.

As to Africa, the uncertainty is so great, that, upon the whole, we do not know whether we should estimate that quarter of the globe at a population of 45, or 90 millions. One third of Africa is so completely unknown, that it is not ascertained whether it contains lakes, or mountains, or sandy deserts. Of the parts which are best known, there is not one concerning which we possess any correct calculations. All that we know is, that the population of Egypt, of the Barbary States, and of the empire of Morocco, has been prodigiously exaggerated. Mention is made of very populous countries on the banks of the Niger; but what traveller deserving of belief has seen those great cities which should have more inhabitants than London? All protensions to certain calculation would be ridiculous; but, if we take a mean term, 70 millions may be considered as the *maximum* of the population of Africa.

Population of America.

150 Millions of inhabitants have been assigned to Ameri-

ca. But there is scarcely *one-third* of this number whose existence can be proved. The Spaniards have scarcely extended their calculations beyond 20 millions of inhabitants of all classes, for the whole population of their colonies; and even this is perhaps a third too much. Brazil has only one million of inhabitants, according to Raynal; but we should now reckon a little more than four millions, including the natives. It would be difficult to discover more than two millions in all the great and little Antilles, deducting those possessed by the Spaniards. The United States have (1821) from ten to eleven millions of inhabitants. English Canada, and Nova Scotia, with their dependencies, can be estimated only at a million and a half. We shall not meet with two millions of individuals in the tribes, or rather the savage families of the interior and north-west. It is evident, therefore, that the whole of America does not contain more than 45 or 46 millions of inhabitants.

Let us sum up the whole of these hypothetical results. General summary.
Europe, the only quarter which is known, may contain 170 millions of inhabitants. Asia has from 320 to 340 millions. All the islands of the Great Ocean, forming the fifth part of the world, may contain 20 millions; we shall leave 70 millions to Africa, and 45 millions to America. The sum total of the human race then, will amount only to 640 or 650 millions of individuals, instead of a *milliard, or* 1000 millions.

We have more satisfactory and correct results as to the proportions which subsist between the births and deaths, and the number of marriages and of living individuals of each sex and of every age [P].

[P] Sussmilch, Divine Order in the variations of the human kind, in regard to births, &c. &c. 2 vols. 8vo. (in German,) 3d edition, Berlin, 1765. (4th edition, posthumous, with a supplement by Baumann, 1775-87.) Euler, Recerches Générales sur la mortalité et multiplication du genre humain, in the Memoirs of the Academy of Berlin, 1760. Lambert, Remarks upon mortality, births, &c. in his Essays on applied Mathematics, Berlin, 1772. (in German.) 9th Mémoire Desparcieux, Essai sur les probabilités de la durée de la vie humaine, &c. &c. Paris, 1746. Wargentin, Mémoires divers sur les tables de mortalité, &c. in the Memoirs of the Academy of Stockholm, vol. xvi. xvii xxviii. et xxxi. Halley's Estimate of the degrees of mortality of

Numerical proportions of deaths according to age.

The natural limit of human life seems to be from 80 to 90 years. Few men survive that period—the greater majority die long before they even approach it. Of all new born infants, one out of *four* dies the first year. *Two fifths* only attain their sixth year; and, before the twenty-second year, one *half* of the generation is consigned to the grave:—the order which death observes in cutting off his victims is one of the most wonderful phenomena in nature—the causes by which it is affected are too numerous and too complicated to be here considered in detail. The unhealthy nature of certain occupations, the impetuosity of the passions, and the corruption of manners, prove no less fatal to life than the original weakness of the human frame. In general, the *mean duration* of human life is between 30 and 40 years; that is, out of 30 or 40 individuals, one dies every year.

This proportion varies in a singular manner, according to sex, localities, and climates, and even from one province to another. In 1774, there was, according to Sussmilch, one death for every 26 men and women in Prussian Silesia, and 1 for every 36 in the March of Brandenburg. In Sweden, according to Wargentin, they reckon 1 in 33 for the men, and 1 in 35 for the women. In Denmark, the proportion is, according to the statistics of Thaarup, 1 in 37 $\frac{9}{11}$, including Holstein. In Norway, according to the same author, they allow 1 in 48 $\frac{4}{5}$. The German-Russian geographers affect to establish a proportion still more favourable for Russia, viz. 1 in 58 or 59; but there is ground to believe that they proceed on erroneous data. It is certain that in small districts, the proportion which

Same proportions according to sex, climate, &c.

mankind, &c. in the Philosophical Transactions, 1691. Arthur Young's Political Arithmetic, 1775. Black's Arithmetical and Medical Analysis of mortality, &c. London, 1789, 2d edition. Short's New Observations on City, Town, and Country Bills of Mortality, London, 1750. Kerseboom, Verhandeling tot een Proeve, &c. that is to say, Memoir upon the manner of knowing population, 1738. id. Aanmerkingen op de Gissingen, &c. that is, Remarks upon the conjectures relative to the number of men, 1742. Petty's Observ. on the Dublin Bill of Mortality, &c. 1683. Ejusd. Several Essays on Political Arithmetic, 1699. Graunt's Annotations made upon the Bills of Mortality, 1666. &c. (these works are quoted in the order of their importance.)

the number of the deaths bears to that of the living inhabitants is sometimes extremely low. In the parish of *Woerdal*, in Norway, the mortality was only 1 in 74, during ten years. In the government of *Woronesch* in Russia, the mortality was that of 1 in 79 $\frac{9}{11}$; but it is physically impossible that proportions so favourable can obtain in a country of large extent. In France, it appears that the computation is 1 death in 35; and that is perhaps the most unexceptionable basis that can be adopted for any country of the same extent.

Mortality in towns and in the country.

It is said that the mortality is much greater in towns than in the country. Wargentin calculates that in Stockholm 1 in 17 men dies, and 1 woman in 21. According to Price, there dies in the large towns of England, every year, 1 out of from 19 to 23; in the small towns, 1 in 28, and in the country, only 1 in 40 or 50.

Aristotle long ago exhorted governments to prevent the accumulation of inhabitants in the cities [1]. Sussmilch compares cities to a continually raging pestilence. Such a sweeping assertion exaggerates the effects of an evil whose existence cannot be denied. The inhabitants of the country enjoy two great advantages over those of towns, a purer air, and a more sober and regular life. On the other hand, rural employments expose those who follow them to so many accidents, and subject them to so many hardships, and to such a miserable mode of living, that it may be doubted whether the real disadvantages in cities are as great as has been supposed. The apparent disproportion is probably owing, in a great measure, to the circumstance of the hospitals being almost always established in towns, and many of the sick being brought to them from the country. Out of from 20 to 21,000 deaths in Paris, it is generally found that from 6 to 7000 have taken place in the hospitals alone.

Causes of longevity.

It appears that the air of open and elevated plains, and of mountains having a free approach, is conducive to lon-

[1] Arist. de Republ. vii

gevity. The same thing may be said of an insular atmosphere, which is always renovated by the breezes from the sea. Russia, Norway, Sweden, Denmark, Scotland, Ireland, and Switzerland, are the countries which furnish the most numerous and the most authentic examples of men and women having had their lives extended beyond the period of 100 years. In these countries, we may reckon one centenarian for every three or four thousand individuals [r]. But, we know that there are many countries in which longevity is common, although we do not exactly know to what extent. Pliny mentions that part of Italy which extends from the Appennines to the Po, and from Placentia to Bologna, as containing a great number of men, from 100 to 150 years of age, at the time of the census which was taken under the emperors Claudius and Vespasian [s].

Rare examples, however, of extreme longevity, of a life of 150 years and upwards, seem to be common to all countries without distinction. If England, the salubrity of which is so highly extolled, has furnished three or four examples of men arriving at the age of from 150 to 169 years [t], Hungary which, generally speaking, is not a very healthy country, has seen the celebrated Pierre Czartan prolong his life to the 158th year [u], and John Rovin, at the age of 172 had a wife of 164, and a younger son of 117. It is in the Bannat of Temeswar, a very marshy district, and subject to the putrid fever, that these examples of longevity, and many others, have been observed [v]. A mode of life, which is sober, and unruffled by tumultuous passions, singularly contributes to longevity. According to the author of a very curious little work [x], called the *Apology for Youth*, 152 hermits, taken in all ages, and under every climate, pro-

Influence of the manner of living.

[r] Sussmilch, Ordre divin, &c. § 483.

[s] Plin. vii. 49.

[t] Robinson, Philosophical Transactions, Nos. 44 and 221. Baddam's Memoir, i. 164. iii. 174. Harleian Miscellanies, vi. art. 8.

[u] Comment. de rebus in scient. natur. et medic. gestis, vol. v. p. 147.

[v] Hanov. Raretés Naturelles, i. 120. (in German) Cramer, Append. ad Medicin. castrens. de climate Hungarico.

[x] Journal de Médicine, vol. lxxiii. p. 310.

duce a sum total of 11,589 years of life, and consequently an average of 76 years and a little more than three months for each; whereas the same number of Academicians, the one half belonging to the Academy of Sciences, and the other to that of Belles Lettres, gives only 10,511 years of life, consequently 69 years and a little more than two months for the mortal career of each. It is therefore not improbable, that in the ages of patriarchal innocence, the period of 150, or even 200 years, was much more commonly attained than it is in our times. This is what the ancients affirm of the *Seres*, of the *Cyrni* of India, of the *Epians* in Ætolia, and of the inhabitants of Mount Athos and Tmolus.

Excess of births above deaths.

In the ordinary course of nature, at least amongst civilized nations, the number of births exceeds the number of deaths. But the proportion varies with the situation. In the country, there is frequently 1 born yearly for every 22 of the population. In towns, the proportion is less favourable, being often 1 to 40, more generally 1 to 35. In this respect, climate occasions a remarkable difference. The most healthy climate is not always that in which there are most children born—for example, in Denmark, the proportion of births to the existing inhabitants is as 1 to 31; in Norway, as 1 to 34. In France, the proportion is as 1 to 29. There are reckoned in Sweden 4 children to a marriage—in France $4\frac{1}{2}$; consequently the ancient opinion, which considered the north as the *officina gentium*, the cradle of nations, although supported by many philosophers [y] besides the antiquary Rudbeck, is altogether destitute of foundation.

Physical causes which multiply the human species.

The manner of life, the nature of the different trades, and the quality of the food commonly used, are circumstances which exert a greater influence than climate upon the propagation of the human race. It has been observed, that people who live upon fish, multiply faster than those

[y] Machiavelli. Storia Fiorent. l. c. 3. Bayle, Nouvelles de la République des Lettre, 1685. January, art. 8. Comp. for refutation. Wargentin, Mem. of the Academy of Stockholm, xvi. 173. (German translation.)

who subsist on nothing but flesh[z]. The fecundity of the women of Sologne, a country by no means healthful, is perhaps to be ascribed to the buck-wheat which constitutes the principal article of food to the inhabitants of that canton; for this kind of grain, as is observed in birds, appears to stimulate the organs of generation[a], whilst rye, on the contrary, is said to occassion infecundity in the fowls that live upon it[b]. Among tribes that lead a wandering life, and are not very numerous, there are fewer children born than in those better peopled countries where the individuals of both sexes are brought nearer together, and are more frequently in presence of each other. In populous countries, however, which have attained a high degree of civilization, the number of births diminishes, owing to the dearness of provisions, which makes it more difficult to support a family, and consequently renders marriages less frequent. The period in which a people subsist principally by agriculture, and when the conveniences of life are easily procured, appears to be that in which population most rapidly advances.

It is owing to the physical influence of the air, the food, and the mode of life, that certain seasons of the year are more favourable to fecundity than others. Pliny calls the spring the *genial season*. Hippocrates had previously observed, that spring was the season most favourable for conception. Aristotle has justly remarked, that the sun and man labour together in the reproduction of man. Observations made in several countries, concur in determining the months of December and January, to be those in which the greatest number of children are born. Local circumstances, depending upon the manner of life peculiar to a nation, may modify or alter this general rule. In Sweden, according to Wargentin, the month in which there are most births is that of September, and the month of January on-

Genial seasons.

[z] Montesquieu, Esprit des Loix, l. xxiii. c. 13.

[a] Mem. de la Société Royale de Medicine, 1776, part ii. p. 70.

[b] Journal de Medicine. vol. lxiv. p. 270.

ly ranks next to it. This fact is easily explained, when we recollect that amongst all the nations of the north, particularly in the country, the season of Christmas and the new year is devoted to festivity and mirth.

Political and moral causes multiplying the species.

The number of births is directly and materially affected by causes of a moral and political nature. The difficulty of finding subsistence is unfriendly to the increase of marriages, and it is only from marriages that a state can hope to see a numerous race of children arise. Libertinism, a community of wives, polygamy, and divorce, have never had a salutary influence on population. It has been shewn by the most authentic calculations, that of two bodies of individuals, equal in number, that which lives in the marriage state produces more children than that which promiscuously indulges in the commerce of the sexes. As to the celebrated institution proposed by Plato, we must refer to that philosopher himself. The community of wives that he thought of, was regulated by severe laws, and had for its object to *limit* population, by purifying it[c]. The polygamy of the East, considering the numerical equality of the two sexes, allows a plurality of wives to one man, only by condemning to celibacy a great proportion of the community. Montesquieu accordingly, has declared it to be very injurious to population[d]; but this philosopher has at the same time defended the facility and frequency of divorce. He has ventured to attribute to this cause the immense number of inhabitants which he assigns to the ancient Roman empire; and he has gone so far as to insinuate that the Christian religion, by inculcating continence, and the indissoluble nature of the marriage union, has diminished the number of the human race[e]. This calumny is easily refuted by the testimonies of the ancients themselves, who all agree in

Of polygamy and divorce.

[c] Plat. de Republ. lib. v.

[d] Lettres Persanes, Let. 110. Esprit des Lois, liv. xvi. chap. 6.; liv. xxiii. chap. 2.

[e] Montesquieu, Lettres Persanes, Let. 110 et 112. Comp. Esprit des Lois, xvi. 15.; xxiii. 21. near the end.

representing the primitive sanctity of marriage as the direct source of the inexhaustible strength of the Roman republic[f], whilst under the emperors, in the age of corruption, Italy would have remained uncultivated for want of hands, had the soil not been laboured by legions, or rather by whole nations of slaves, collected together from all parts of the world[g]. All the evil which has actually arisen from the celibacy of the clergy—a celibacy no where enjoined in the Gospel—cannot countervail the services which Christianity has rendered, merely with regard to the increase and preservation of our species.

The immoderate use of strong liquors tends to enervate the frame, and to exhaust the powers of propagation. An active, sober people, equally moderate in their passions and their pleasures, will always be superior in fecundity to a people debauched by luxury, effeminacy, and voluptuous enjoyments. A proof of this may be obtained by comparing an agricultural country with one which is filled with vineyards. It appears to be proved that a square league laid out in fields, can furnish occupation and food only for 1390 individuals, whereas a space of equal extent, planted with vineyards, supports 2604 persons[h]. Why then are districts abounding in vines, often more thinly peopled than agricultural provinces under the same climate? Why are the vine-dressers so often in miserable circumstances? For no other reason than that drunkenness is more prevalent in such a district, and because the annual produce of the vine is more uncertain than crops of grain.

Agricultural and vine countries.

"The period of puberty arrives sooner," it has been said, "in warm and southern countries, than in cold climates, as those of the north, and of elevated mountains." This commonly received opinion must be understood with

Period of puberty.

[f] Dionys. Halicarn. ii. Valer. Maxim. ii. c. 4. Aul. Gell. iv. c. 3. Plut. Parall. de Théséo et Romulo. Cic. de Republ. lib. vi. "Majores nostri *feminæ stabilita* matrimonia esse voluerunt."

[g] Plin. Hist. Nat. xxxiii. 10. Seneca de Tranquill. c. 8.; De Brevit. Vitæ, c. 12. Athen. Deipnosoph. Lips. de Magnitudine Romana, ii. 15.

[h] Discours sur les Vignes, Dijon, 1756.

some limitation. It is true, for example, that the Barbary women are generally mothers at 11 years of age, and cease to bear children at 30 [i]. Buffon, quoting from Thevenot, says, that in the kingdom of the Deccan, boys are married when 10 years old, and girls when eight, and that there are some who bear children at that age; so that they may be grandmothers before they are 20. But if this were purely the effect of climate, as Buffon imagines, a very singular consequence would follow. The climate which the Negroes of Senegal inhabit, is certainly warmer than that of Barbary, and even than that of the peninsula of the Deccan. If then it is the influence of climate alone which accelerates the period of puberty amongst the nations of India, and which fixes it at 10 or 11 years of age, the same influence should also fix the period of puberty amongst the Negroes at seven or eight years. But so far is this from being the fact, that all the accounts which we have consulted, seem to prove that the age of puberty amongst the Negroes is not much earlier than amongst the southern nations of Europe. It appears, then, that even in the torrid zone, the physical phenomenon in question, depends rather upon the *difference of the race*, than upon that of the climate.

Examples of variations in this respect.

There are other facts still more conclusive. All the Russian and Danish travellers who have given us written accounts of Lapland, and the other countries in the neighbourhood of the Frozen Sea [k], agree in stating that the women of these regions are not only very lascivious, but that they become marriageable at an early period. A Frenchman who has seen much, and seen with observation [l], assures us that the Swedes become sensible to the passion for the sex at the age of 12 years. In Russia the peasants often marry at the same age. In the Vivarais, a mountainous and cold tract of country, the natives are as soon marriage-

[i] Shaw's Travels in Barbary, 4to, p. 241.

[k] Hægstrom, Klingstedt, &c. &c.

[l] M. Fortia de Piles, dans le Voyage de deux Français dans le Nord, tome ii. p. 422.

able as in the other provinces of the south of France [m]. The savages of America, who dwell under the line, arrive as late at puberty as those who live near the pole. With them the men do not marry before they are 30, nor the women before 20.

General inference.

It appears then that we should consider this physical difference rather as inherent in the particular race than as dependent on climate. The cause is often to be found in the extreme corruption of manners. Be this as it may, the phenomenon of which we speak has probably but little influence on the number of births, and none whatever upon the increase of population. In the first place, it is observed, that in every country where women are marriageable at a very early period, they also sooner cease to bear children: in India they become old at 30. In the second place, the children in those countries are more feeble, and subject to greater mortality.

Numerical proportions of births and marriages.

This last observation can even be extended indiscriminately to all nations; we should always beware of inferring an increase of population, *solely* from the number of the births appearing to be greatly superior to the number of the deaths. When this *excess* is extremely disproportionate to the number of deaths and marriages, there is reason to suspect some want of exactness in making out the lists, or some extraordinary physical circumstance. *The proportion of births to marriages*, on an average, and in a country of some extent, can scarcely be more than 5, or less than 3 births to one marriage. The ordinary proportion, in the most civilized countries of the world, is four births to one marriage. *The proportion* between *births and deaths* is, one year with another, from 101 to 150 for every 100. This last proportion indeed occurs only in some provinces of small extent, and singularly favoured by nature. Every proportion higher than this, with regard to an extensive country, ought to be viewed with suspicion, unless verified by calculations and registers of undoubted correctness and

[m] Mémoire de la Société royale de Médecine, 1780 et 1781, part II. p. 130.

authenticity. To mention only one example: the Russians may be permitted to assert that almost every year, (even in time of war,) there are more than one million of individuals born in the Russian empire, whilst only from 500,000 to 600,000 die. But we also must be allowed to express our doubts as to these marvellous results, and to ascribe, in part, this disproportion between the deaths and the births, to the carelessness of those who keep the registers. Euler has constructed the following table, by means of which we may see, at a glance, in how many years the population of a country may be doubled under certain conditions [n].

In a Country of 100,000 *inhabitants, the Mortality being* 1 *in* 36.

Table of increase of the species.

The deaths being to the births, as,	The surplus of births will be	This surplus will make of the sum of the living	The doubling of the population will take place in
10 to 11	277	$\frac{1}{361}$	$250\frac{1}{12}$ years.
—— 12	555	$\frac{1}{180}$	125
—— 13	722	$\frac{1}{138}$	96
—— 14	1100	$\frac{1}{90}$	$62\frac{3}{4}$
—— 15	1388	$\frac{1}{72}$	$50\frac{1}{4}$
—— 16	1666	$\frac{1}{60}$	42
—— 17	1943	$\frac{1}{51}$	$35\frac{2}{3}$
—— 18	2221	$\frac{1}{45}$	$31\frac{3}{4}$
—— 19	2499	$\frac{1}{40}$	28
—— 20	2777	$\frac{1}{36}$	$25\frac{3}{10}$
—— 22	3332	$\frac{1}{30}$	$21\frac{1}{3}$
—— 25	4165	$\frac{1}{24}$	17
—— 30	5554	$\frac{1}{18}$	$12\frac{1}{2}$

The same mathematician, founding on data extremely favourable to the propagation of the species, has constructed a table, the general result of which is, that the human race might be tripled in 24 years, and that at the end of 300 years the posterity of one couple migh amount to 3,993,954 individuals.

Taking the total number of the human race at 700 millions, (which is rather high,) the ratio of the deaths to the living population as 1 to 33, and that of the births

Proportion of births and deaths in a given time.

[n] Euler, Tables communicated to Sussmilch, Ordre divin, chap. viii. §§ 152, 156, 162.

to the living as 1 to 29½, we shall have for the whole globe,

	Births.	Deaths.
In one year,	23,728,813	21,212,121
— one day,	65,010	58,120
— one hour,	2,708	2,421
— one minute,	45	40
— one second,	¾	⅔

Whence it follows, that the sum total of the human race would, in one year, be augmented by an accession of 2,516,692 individuals, were it not for wars and pestilences. This augmentation would, in 100 years, bring the number of men up to 3,216 millions. The earth might, perhaps, support a still greater number; but all the records of history seem to concur in showing that the increase of the human race has hitherto advanced at a much slower rate.

Numerical proportion of the two sexes.

The *proportion between the numbers of the two sexes* is a matter of great importance, both in statistics and legislation. In Europe there are always more boys born than girls, in the proportion of 21 to 20, or, according to others, of 26 to 25. On the other hand, the mortality also is greater amongst the male children, in the proportion of nearly 27 to 26; in consequence of which, about the 15th year, the numbers of the two sexes are brought almost to an equality: there is, however, still a surplus in favour of the males. But this surplus in the number of the men, even though it were three or four times greater, is carried off by wars, by dangerous voyages, and by emigration, to the casualties of which the female sex are less exposed. Thus, the final result of this is, that in our climates the women are always more numerous than the men. This difference is particularly observable at the conclusion of a long war. According to Wargentin, it amounted in France, after the seven years war, to 890,000 in 24 or 25 millions of souls; and in Sweden, after the Northern war, about 127,000 in a population of two million and a half.

At the same time the difference of numbers between the two sexes is not in Europe sufficiently great, nor indeed sufficiently steady to warrant any conclusion unfavourable

to the system of monogamy, that is, of marriages between one man and one woman. Such marriages only are fitted to insure domestic happiness, and to maintain pure morals; they are besides sanctioned by the soundest maxims of political economy; and none can doubt that the prevalence of *polygamy*, or the marriage of one man to several wives, would prove fatal to the welfare of Europe.

Are there more girls born in the east?

Some travellers [p] have imagined that in warm climates there are more girls born than boys; and as the male sex is liable to more rapid destruction in such climates than in ours, the surplus of women must become very great; hence Montesquieu concludes that polygamy amongst those people admits of a very plausible excuse; but the position from which he sets out is altogether unfounded. The researches of Father Parennin in China [q], the lists of baptisms kept by the Danish missionaries of Tranquebar [r], the various censuses taken by the Dutch at Amboyna and Batavia [s], and the observations made at Bagdad and Bombay, by the judicious Niebuhr [t], have demonstrated that the number of children of both sexes is not more disproportionate in the East than in Europe.

It is alleged with more reason, that there are some nations who, being in the habit of selling a number of their women to foreigners, experience a deficiency of them at home, which has obliged them to establish *polyandrism*, or the marriage of one woman to several husbands [u]. Such a practice, if it does exist, is evidently the least favourable to population.

[p] Kæmpfer, Description du Japon, i. liv. 2, chap. 5. A Collection of the Voyages of the East India Company, i. 346.

[q] Lettres édifiantes, xxvi. recueil, p. 8. (Paris, 1743.)

[r] Sussmilch, l'Ordre Divin, &c. § 418.

[s] Valentyn, Beschryving van Amboina, ii. p. 342. Struyck, Nader ontdekkingen noppens den staat van het menschelyk geslagt, p. 104, (in Dutch)

[t] Niebuhr, Description de l'Arabie, i. 102, *sqq*

[u] Duhalde, Description of China, iv. 461. Strabo (Description of Media,) ix. 798. edit. Almel, Compare Michaelis. Mosaic Right, ii. 199. (in German.)

General proportion of sexes, ages, states, &c.

It has been commonly computed that a district, in which there are 10,000 infants born yearly, must contain in all, 295,022 inhabitants of both sexes, of whom 93,003 should be children below 15 years, and 202,019 persons above that age.

Amongst these individuals, there will be at the most 23,250 monogamic marriages, (the mean duration of which may be estimated at 21 years,) 5,812 widows, and 4,359 widowers, the rest single.

BOOK XXIII.

Continuation and Conclusion of the general Theory of Geography. Of Man, considered as a Moral and Political being; or, Principles of Political Geography.

Political Geography.

We have for a long time considered the earth as a physical body, having relations to other physical bodies which surround it, or which dwell upon its surface. No sooner, however, had man become the subject of our inquiries, than we have seen *physical geography* gradually give place to *political*. This branch of our science considers the earth according to its political divisions, and in its relations to the different civilized societies which are established upon it. It is evident that this department of geography has, as well as the others, general principles of its own, which, taken collectively, form a *theory*, and the knowledge of which ought to precede the study of particular descriptions. Of these principles, however, those which, from their having a foundation in the nature of our being, do not change with the changes of human opinion, are few in number. The other relations vary, if not in different kingdoms, at least in different parts of the world; and this induces us to confine ourselves here, to a rapid view of the former class of principles, reserving for the others their proper place in our particular introductions to the description of each grand division of the globe.

Articulate and rational language.

Articulate language, the noble inheritance of human nature, forms the great bond of civil society. Few animals have language which is *articulate*, or possessed of distinct

and uniform sounds, and even these scarcely amount to ten or twelve inflexions of the voice. No animal has a *rational* language, that is, a language whose different sounds express uniformly and distinctly general ideas. This faculty of expressing our ideas by words, insures of itself the continued exercise of our memory—and without memory where would be the understanding? It is only by means of speech that man is a reasonable being. It is speech which renders the observations, the feelings, the discoveries of the individual, the property of the species; thence arise sciences, arts, civilization, and the unlimited perfectibility of the human race. Language, considered as a moral and physical faculty, appears then to be innate to man; but the choice of sounds, their modifications and their combinations, must have depended upon the will of man; natural logic has unquestionably had its influence, and, in addition to it, the passions of individuals, their habits, the delicacy of the organs, the nature of the climate, and the state of society, would all of them contribute to produce effects. The *primitive tongues*, possessing a very scanty stock of words, simple as the manners of those by whom they were spoken, would naturally be lost by becoming confounded with the more perfect dialects which sprung from them, just as the primitive nations have disappeared, by merging in those nations celebrated in history, to which they had originally given birth.

Primitive tongues.

But although all attempts to discover the primitive tongue appear now to be completely abandoned, philologists still do not despair of fixing the number of *mother tongues*, that is, of those which, in the principal words of which they are composed, in the grammatical inflexions which they adopt, and in the syntax which they follow, present to us a character independent of every other tongue. These mother tongues, however, as they suggest the possibility of a common origin, from their exhibiting some distant traces of resemblance, form amongst themselves, *families*, without any of them being able to claim pre-eminence in point of antiquity.

Mother tongues.

It may well be asked, By what criterion shall we ascertain the high antiquity of a language? Should it be chiefly composed of *vowels*, as the *Otahcitan*, the *Zend*, the *Basque* or *Iberian*, the *Algonquin*, the *Caribbee*, the *Esquimaux*? But these tongues, almost entirely consisting of vowels, have no mutual resemblance in any other respect. Is the most ancient tongue *monosyllabic*, as M. Adelung[a] would have us to believe? But the Chinese, the *Thibetan*, the *Tonquinese*, and the *Siamese*, which on this supposition would be the primitive tongues, bear no resemblance in their sounds to the language of the Celts or the Negroes. If we are desirous of examining languages as to their grammatical forms and their syntax, we shall find, on the one hand, some, in which the relations of genders, persons, modes of action, and of time, are expressed by the most ingenious, delicate, and profound combinations, as in the Sanscrit, the Hebrew, and the Greek; and, on the other hand, we shall see others in which all these relations, though indispensably necessary to thought, are attempted to be marked only by clusters of vague, obscure, puerile, and arbitrary words, as in the Chinese, the Celtic, the dialects of the Negroes, and those of New Holland. Some might say that these last-mentioned tongues should be the most ancient, as being nearer to nature, in the vulgar acceptation of the word. History however, clearly proves to us, that the Hebrews, the Indians, and the Greeks, were at least as ancient as the Ethiopians, the Celts, and the Chinese. It is then indifferent where we begin to count the links of a chain which is lost in the darkness of ages. We shall first mention the *family* of the *Indo-Germanic* tongues, which extend from the banks of the Ganges to the shores of Iceland. The principal divisions of this *family* follow in the geographical order which we are about to point out. The *Sanscrit* prevailed anciently throughout all Hindostan. From the Sanscrit descend the Dewanagara, the purest idiom of

Families of tongues.

Different characters of tongues.

Family of Indo-Germanic tongues.

The Sanscrit, Dewanagara, &c.

[a] Mithridates, ou Notice générale des langues, par Adelung, 2 vols. 8vo. vol. i. p. 120.

India, the Tamulic, and several other dialects spoken in the Decan. Besides a certain number of roots or original words, which the Sanscrit has in common with the Greek, the Latin, the Sclavonic, and the German, it displays also, in its numerous declensions, and in its extended conjugations, the most striking affinities to these mother tongues of Europe, particularly the Greek and Latin. Persia presents to us three ancient languages: the Zend, which appears to have been the sacred language; the Pelhevi, the language of ancient Media; and the Parsi, a dialect of Persia, whence descend in part the modern Persic and the Kurde. In all this group of languages there are a great many German words to be found; the grammar, infinitely less rich, and less regular than that of the Sanscrit, resembles, in several points, the genus of the German and English languages. The hissing consonants, unknown in the Sanscrit, appear already in the Parsi.

The Zend, the Pelhevi, &c.

Greek tongues.

The Greek tongues form one of those kinds of which we know best the different species. The Hellenistic, or Greek proper, had three dialects: the Doric, which is entirely extinct; the Ionic, to which the modern Greek appears to have the greatest resemblance; and the Æolian, which, being very early transplanted into Italy, became the parent of the Latin. To the class of *Sclavonic tongues*, which, in their declensions, and several other circumstances, resemble the Greek, belong the Sclavonic, Illyrian, the Polish, the Bohemian, the Russ, and the different remains of the Wende tongue. The language of the Dacians and Getæ was probably an old branch of this class. In the class of *Germanic tongues*, a very ancient division is perceived: the Frisonian, French, Saxon, Anglo-Saxon, and Alemanic tongues, form the Teutonic branch; whilst the Mœso-Gothic, preserved in Ulpila's version of the Gospels, the Icelandic, and modern Scandinavian, in its two principal dialects the Swedish and the Danish, constitute the Gothic branch; these branches differ like the Greek and Latin.

Sclavonic tongues.

Germanic languages.

In the neighbourhood, and even in the midst of this great family, composed of the more perfect mother tongues,

we perceive other families also of great antiquity, but which, in their clumsily constructed grammar, nowise resemble either them, or the Indo-Germanic tongues. Such, in the west of Europe, are the Celtic tongues. The principal species of which are the *Erse*, spoken still in Scotland and Ireland; the *Welch*, or *Cimbric*, preserved in the principality of Wales; and the *Celtic*, properly so called, of which the Low Briton is a remnant that has undergone much admixture. In the Spanish peninsula, there existed an *Iberian* or *Cantabrian* language, of which the *Basque* presents to us some interesting fragments; and which, while it rivals the Celtic in primitive simplicity of structure, differs totally from it in its vocabulary. In Italy and Greece, the *Pelasgian*, *Thracian*, *Illyrian*, *Etruscan*, and other languages, disappeared before they were observed by philosophers. Perhaps the *Albanian* is a remnant of the *Illyrian*.

Families of the Celtic tongues.

Basque language.

Languages, Pelasgian, Illyrian, &c.

From the wrecks of all these ancient tongues, from their mixture with the Latin, and then with the Germanic, Sclavonic, and even Arabic dialects, have sprung mixt languages; such as the *Valaq*, the *Italian*, the *Provençal*, the *French*, the *English*, the *Spanish*, the *Portuguese*.

Mixed languages.

To the north-east of Europe, we discover the only scattered remains of the great family of Scythico-Sarmatic languages.

Family of Sythico-Sarmatic language.

It is the *Finnish*, together with the *Esthonian* and the *Livonian*, that we may consider as the most distinct class of all the other languages of the globe, or at least of all those of Europe. The *Lapponic*, the *Permiaque*, with various other dialects spoken along the Uralian Mountains, and the Wolga, and the *Hungarian*, originally of the same regions, always exhibit a great family likeness. But in the *Lithuanian*, and its dialects, we see the phenomenon of a tongue differing from the *Indo-Germanic* language in its radical words, and which at the same time possesses in its grammar astonishing delicacy of structure, and resources unknown to the other *Scythian* languages; and, in truth, an undoubted affinity to the *Greek*.

Lithuanian.

Caucasus, situated in the centre of the regions in which

the Indo-Germanic languages prevail, far from presenting to us the common source whence these languages derived their origin, interrupts the chain of them; and in the *Georgian*, the *Circassian*, the *Armenian*, and some other singularly rude and simple dialects, furnishes us with a distinct family, or rather a distinct group of languages, little known, and unquestionably of great antiquity.

Aramean tongues. But if we extend our view to Syria, Mesopotamia, Arabia, and Abyssinia, the *Aramean* languages draw our attention by the renown of their ancient civilization, abundance of guttural sounds, vast store of words, multiplied inflexions of the verb, great simplicity, and even poverty in other respects. Such appear to be the common characters of these tongues, amongst which we shall distinguish

Arabic. the ancient and modern *Arabic*, with its colonies; the *Moresque*, current over all North Africa; the *Geez* and *Amharic* dialects, spoken in Abyssinia; and the different branches of the Arabic, which extend along the eastern

Hebrew. coast of Africa; the *Hebrew*, in its various modifications from the ancient idiom of Moses to the *Chaldee*, *Samaritan*, and other dialects now extinct, with the exception of

Phenician. the *Rabbinica* or modern Hebrew; the *Phenician*, of which the *Punic* or Carthaginian is the most celebrated branch, and of which the low Arabic-*Maltese* preserves perhaps some remains; the *Syriac* or *Aramean*, properly so called; finally, the *Chaldean*, which differs from the Chaldaic Hebrew.

Denomination of Shemitic languages. As the most of the nations that speak these languages descend, according to Moses, from Shem, this stock has been distinguished under the general name of the *Shemitic* languages, while the term *Japhetic* has been given to the Indo-Germanic languages. But, by admitting these denominations, we are subjected to the inconvenience of attributing to the descendants of Ham all the other languages, from the Celtic to the Mexican and from the Negro to the Chinese, notwithstanding their evident original difference.

The stock or family of the languages of Eastern Asia, or of the Monosyllabic languages, differs entirely from that

of the Indo-Germanic languages. It comprehends the *Thibetan*, the *Chinese*, the *Burman*, composed of the dialects of Pegu, Ava, and others; the Siamese, and the Annamic, in the dialects of Cambodia, Tonquin, and Cochin China. All these languages are more or less deficient in contrivances for marking directly the cases, genders, numbers, moods, and tenses; those who speak them are obliged to supply the absence of grammatical forms and rules of syntax, by intonations, gestures, and a sort of hieroglyphic writing.

The north of Asia contains three or even four kinds of languages, infinitely superior to the monosyllabic tongues. The *Turcoman*, *Bucharian*, and different *Turkish* or *Tartar* languages, spoken by the Tartars, properly so called, from the Crimea and Casan to Tobolsk, and in Chiwa by the Ottoman Turks; other tribes are remarkable for the exactness of their grammatical structure, particularly with respect to conjugations, and for the power of forming compound words with as much facility as the Greek, the Persian, or the German. Several German radical words occur in these. The *Mongol* language, deficient in grammatical combinations, possesses, however, complete declensions; it abounds in vowels and harmonious sounds. The *Mantchou* language, though full of monosyllabic words, possesses a very complete and very varied grammatical structure; and what is singular, it contains some Greek and German roots. The *Korean* and *Japanese* appear to be closely related to the Mongol and Chinese. The *Tungusc* is a dialect of the Mantchou; the *Samoyede* differs from it. We are inclined, however, to the opinion, that all the languages of Central and Northern Asia, with which we are most familiar, belong to one family.

Turkish and Tartar languages.

Mongol, Mantchou, &c. tongues.

The Oceanic countries, from Sumatra to beyond Otaheite, present to us a series of dialects which have all some relation to the Malay,—a language of the eastern peninsula of India. The same kind is found at Madagascar, but in a more perfect form, with a more methodical grammar. There are unquestionably some general languages scattered

Tagalic, Taitienne languages, &c.

over this immense archipelago. The *Tagalic* and the *Bissago* of the Philippine Islands are found in the Moluccа and Marian Islands; traces of them are discernible in New Zealand. These two languages have some affinity to the Mantchou and Mongol. The *Taïtian* is distributed through all the small islands of the Great Ocean. More to the west, the Negro tribes of New Caledonia, New Guinea, of Van Dieman's Land, and of New Holland, speak dialects which probably form one or more separate stocks.

Singular custom.

In the Oceanic countries a singular custom prevails: the princes, on their accession to the throne, change several words of the national language. This custom obtains in Africa. The numerous dialects of the savages should then be, partly at least, composed of cant words, created and adopted by families, insulated and obliged to distrust one another. This hypothesis has much probability. The languages of Africa, which are very little known, have appeared innumerable to some travellers. Others think that this is true only of the idioms of the Negroes, properly so called. Indeed, from the Senegal to Cape Negro, the language spoken varies often from village to village. The languages of the Yalofs, of the Voulahs, of the country of Dahomey, of the kingdoms of Benin and Congo, as well as that of inland Nigritia, present, however, the same combinations of consonants, and some common words. In the north, the language of the Brebers or Kabyles, appears to us as the last remains of tongues formerly spoken along Mount Atlas and the Mediterranean. The Coptic, a remnant of the ancient Egyptian, is well known. The researches of M. Quatremere will, perhaps, inform us whether this language is connected with those of the original inhabitants of Nubia and Abyssinia. Upon the eastern side, from Magadaxo to the country of the Hottentots, the geographical names shew the prevalence of the *Caffre* language, which, even amongst the Betjouanas, preserves evident traces of a strong mixture with the Arabic. At the southern extremity of this part of the world, the Hottentots speak a particular dialect, full of clickings and shakings of the tongue, which pro-

Languages of the Negroes.

Breber language.

Coptic.

Caffre.

Hottentots.

duce sounds similar to the cries of birds. Their tongues are shorter and thicker than ours [b].

Could the different character and genius of human languages have been the result of a hereditary difference in the organs of speech? If this principle were admitted, very important conclusions might be drawn from it. For example, the Chinese, the Esquimaux, and the Mexicans, cannot pronounce the letter *r*, they supply its place by *l*. Are they all then of a common origin? But we must carefully guard against admitting with too much confidence these kinds of analogies, since they might grossly mislead us. For example, it has been observed that the compound consonant *mb*, which a European can scarcely pronounce at the beginning of a word, was common to the languages of the Negroes and the South Americans. The observation is correct, but we cannot infer from it the common origin of these tribes, since the confounding of *m* and *b* occurs in the Æolian dialect of [c] the ancient Greeks, who, undoubtedly, are descended neither from Peruvians nor Negroes. There are, in Norway, whole families who commence every word by the consonants *ng*, so common in the dialect of the Negroes of Angola. *B* is confounded with *w* by the Greeks, the Gascons, and the Russians. The guttural sounds of the Arabians are to be found in the German, a language of a different stock. These examples show the great difficulty of ascertaining how much, in such singular anomalies, should be referred to physical and unvarying causes, and how much arises from the influence of mere caprice.

Influence of the organs upon language.

The American languages are scarcely better known than those of Africa. Humboldt thinks that there are in that quarter of the world a very great number of languages independent of one another. What increases their number is

American languages.

[b] Lichtenstein, dans les Archives ethnographiques, par Vater et Bertuch, i. 259, [illegible]

[c] B[illegible] for Βαρβίτης; Μιλλω for Βιλλω the Latin Meo, from the Greek, B[illegible], &c.

the custom adopted by every new dynasty of introducing a new language. Thus, the *Toultec*, the *Huaztec*, and the *Aztec* languages have been successively current in Mexico. These languages, in which a laborious search has been made for some slight affinities to the Mongolic dialect, are extremely complicated both in their etymology and their syntax.

Toultec and Aztec languages.

The *Cherokee*, *Iroquois*, and *Algonquin*, or Huron, appear to be the most widely extended of those that are spoken between Hudson's Bay and the Gulf of Mexico: they are poor and plain. The *Esquimaux* or Greenland tongue, which is current over all the polar region, presents an odd fantastic structure, from the joining together of many simple words and even parts of discourse in one single word of immoderate length. In South America, the *Caribbee* or *Galibbee*, a sonorous language, prevails to the north of the river of the Amazons, as it did formerly in the little Antilles. Several ancient languages, regular in their composition, have disappeared in New Grenada, Quito, and Peru; but the fine language invented by the Yncas, the *Quichua*, remains in general use even amongst the Spaniards. The *Guarran* language is so prevalent in Brazil and Paraguay, that the Spaniards and Portuguese, even in several of the towns, speak no other. Different dialects, little known, exist in Chili and in Patagonia. The Pecherais, in Terra del Fuego, have a dialect peculiar to themselves.

Iroquois, Algonquin, &c.

Caribbee.

Language of the Yncas.

Guarran.

These are the principal languages spoken by the human race. How wide the distance in this scale between the dialect of the Negro and the Chinese, who scarcely distinguish the singular from the plural, to the Greek language, in which the most tender and the most profound thoughts can be fully developed, and permanently fixed! There are languages which have no expression for objects which are not perceived by the external senses, such as the soul, or God. There are some which have no term equivalent to the verb *to be*, or the substantive *world*. But if metaphysical knowledge appears to be denied to the great majority of the human race, all nations, even the most savage, believe in the

existence of some invisible beings possessed of power superior to man. The various manners in which nations manifest this sentiment, constitute so many different *religions*— the external acts which are the result of such religious belief, form modes of *worship*. Religion and worship.

The name of *Polythcism* is given to every system of religion which admits the existence of several gods, whatever be the nature and dignity which it assigns to them. Of this there are several kinds. The grossest of all is *Fetichism*, or the adoration of Fetich. By Fetiche[d], is understood all sorts of animated or inanimate substances, which the priests of these religions hold out to the savages as beings that are enchanted or endowed with some magical and divine power. These absurd superstitions prevail amongst the ignorant nations of the coast of Guinea, and amongst a great many other savages. They are blended with a variety of other religions. The *Ox Apis*, the *Dog Anubis*, were perhaps the Fetiches of the Egyptians[e]. The black stone worshipped at Mecca before Mahomet, and the god *Phallus* of the Romans, were undoubtedly of the same number. Fetichism.

Sabeism holds a more elevated rank, that is to say, the worship of the heavenly bodies, the sun, the moon, and the stars either separately, or altogether. This very ancient system, spread over the whole extent of the globe, is blended with all the other systems of superstition. But it no longer exists entirely pure, except amongst some insulated tribes. It has its name from the Sabeans, or Sabians, an ancient people of Arabia. Sabeism.

Three hypotheses have been formed as to the nature of the universe; *materialism*, or *pantheism*, which supposes that every thing which exists is penetrated with a divine spirit; *dualism*, which admits the existence of two eternal beings, God and matter, or the good and bad principle; and the system of the *Emanists*, which represents all beings, Pantheism. Dualism, &c. &c.

[d] A word which comes from the Portueguese word *Feitiso*.

[e] Debrosses du Culte des Dieux Fetiches, ou parallèlle de l'ancienne religion d'Egypte, &c. 1760.

the good and the bad spirits, as having emanated from a supreme God [f].

Pantheism, modified by the institutions of particular nations, and blending itself with Sabeism, became systematic. Polytheism. or mythological *Polytheism*. Under this name may be classed all those schemes of religious belief, in which the attributes of the Deity are personified as separate divine beings. These systems then, are barbarous and irrational. They are, however, well suited for poetry and the fine arts, and have been received amongst the most civilized nations of antiquity. They are of several kinds, very different from each other, but reducible to *three* classes. The most gross Egyptian Polytheism, or Zoomorphism. is the religion of the *Egyptians*, in which the attributes of the divinity were represented under the figure of animals, which may perhaps account for their hieroglyphic writing. This may be termed *zoomorphism*. In the religion of the Greeks and Romans, human nature, exalted however, and embellished, served as a model for divers personifications of the Deity. This then, was *anthropomorphism*, which was varied to infinity. The worship of national heroes modified the polytheism of the Greeks and Romans. Veneration for the dead, a very natural sentiment, mingled with all religions; but of some it appears to have formed the chief part. This was the case with the *Celts*, whom, for other reasons, we number with the Polytheists. Amongst other nations, such as the Syrians, the Chaldeans, and the Phenicians, the worship of the stars and the physical energies of the earth, appear to have predominated.

Grecian Polytheism, or Anthromorphism.

Polytheism of the Bramins, or Theomorphism. In the religion of the *Bramins*, the Supreme Being is supposed to be disguised under different forms, divine, human, and animal. We think that this belief might be considered as the source of all the others, even of Fetichism; but it might be equally asserted that the religion of the Bramins is merely ennobled Fetichism. *Theomorphism*, the religion of the Hindoos, is the best supported of all the ancient systems of worship; it still exists. Two of its

[f] Cudworth, Intellect. System. chap. i. iii. Dupuis, origine des Cultes

[illegible] in the North and East of Asia. The one is [illegible], the head of which is the *Dalaï Lama*, a [illegible] who is supposed never to die. This religion, mixed [illegible] tichism, is spread over Tartary, Mongolia, and [illegible] the other branch is *Buddism*, or the *Braminic* system reformed by Budda, named also Somonocodom: It is established amongst the Bramins in Siam and in Ceylon. The ancient religion of Japan is a kind of Schamanism, from whence has arisen the religion of *Fo*, which is that of the multitude in China, and which is only a degenerate branch of that of Budda; the priests are called *Bonzes*.

Schamanism.

Buddism.

The system of two opposite principles, and that of emanations must naturally run into each other, whenever the Dualists grant the least superiority to one of their principles, or the Emanists admit the possibility of a revolt against the Supreme Being. This is the reason why the religions derived from these two sources are scarcely distinguished from each other. They belong altogether to *Monotheism*, if we agree to apply that name to every religion which recognizes only one true God, whatever may be the crowd of spirits, fairies, angels, and devils, which surround him. There are three ancient religious systems which have for their basis a dualism more or less avowed. The first is the religion of the Magi, or of Zoroaster, denominated also *Mithriatic* worship. There is a Supreme Being, from whom emanated two principles, the one good, Oromastese, the other bad, Arimanes—they fight with each other; but the good will finally obtain a complete victory. This belief, which has been disfigured by the Greek historians [g], is still preserved amongst the Parses, or Guebres in Hindostan.

Monotheism.

Religion of the Magi.

The ancient religion of the Sclavonian nations is less known. Biel-bog, the white god, and Czerno-bog, the black god, appear in it as two antagonist powers. Some authentic records give us an idea of *Odinism*, which prevailed in Scandinavia; Odin, the chief of the good gods; Surtur, the principle of physical evil, the destroyer of the world; Lok, the

Religion of the Sclavonians.

Odinism.

[g] See the article Persia.

principle of moral evil, and all the other gods, are in a state of dependence upon Alfader, or the universal Father [h].

Through so many ingenious errors, or fanciful and absurd dreams, celestial truth was opening up in silence the right path. An obscure and inconsiderable nation acknowledged the absolute unity of the divinity as the basis of their religious faith. *Judaism*, some of whose rites and ceremonies resemble those of the Persian Magi, and of the Egyptian Priests, is now divided into two principal sects—namely, that of the Karaïtes, who acknowledge as divine only the books of the Old Testament; and that of the Rabbinists, who attribute an authority almost divine to the collection known under the name of the Talmud.

Judaism.

Christianity. *Christianity*, for the introduction of which the Jewish scriptures and the Jewish polity paved the way, sprung up in the bosom of Judaism, and although in consequence of corrupting its pure doctrines, by mingling with them the principles of the Platonic philosophy, and encumbering its few and simple rites by the inventions of human fancy, it became soon divided into an infinity of sects and systems, it now sheds its benignant and liberal influence over the most civilized countries, and in all quarters of the world [i].

Greek Church. The Greek or Eastern Church, which was most orthodox in the fifth and sixth centuries, is tolerated in Turkey, countenanced in Hungary, Sclavonia, Dalmatia, and established by law in Russia. Amongst its various branches, we may distinguish the *Nestorians* in Turkey in Asia, who at one time were very numerous in Tartary, in Mongolia, and even in China; and the *Monophysites*, who comprehend the Copts in Egypt, and the Armenians and Jacobites in Abyssinia.

Latin church. The Latin or Western Church is divided into two great parties.

[h] See the article Scandinavia.

[i] Brerewood, Recherches sur la diversité des langues et des religions, trad. de l'anglais par La Montagne. Paris, 1640.

The *Catholic*, Apostolic, or Romish Church, comprehends within its pale the greater part of France, Italy, Spain, Portugal, Austria, the extensive Spanish and Portuguese Colonies in America, Africa, and Asia, and three-fourths of the population of Ireland. The *Pope* is the spiritual head. The Gallican Church is distinguished by privileges peculiar to itself, which oppose an invincible barrier to the usurpations of the Pope. The United Greeks, who forsook the communion of the Oriental Greek Church, form an inconsiderable appendage to the Catholic Church. Catholicism.

The *Protestant* Churches are divided into three branches: *Lutheranism*, or the Evangelical Church, is supported by the state in England, Prussia, Saxony, Hanover, Denmark, Norway, Sweden, and Livonia; *Calvinism*, or the reformed Church, is most prevalent in Switzerland, in some countries of Germany, and in Holland; it is the established religion in Scotland, under the name of the Presbyterian Church. We may identify with the reformed church, the *Independents*, or *Congregationalists*, who are so numerous in the United States that they have more than 1000 congregations. The English, or Episcopal Church, is distinguished from the other Protestant denominations merely by its maintaining the order of the episcopal hierarchy. It is the established religion in England; and in Ireland, although the faith of the minority, it is upheld by the strong hand of power. Without advocating any system of intolerance, or wishing to insult men entitled to respect, we shall here give the name of sect to every religious party who have not become in any place sufficiently numerous to have their tenets embraced and patronized by the state. The principal Christian sects are: The *Unitarians*, *Socinians*, or *Antitrinitarians*, whose opinions are protected in Transylvania and in Russian Poland: a very great number of Catholics, of Lutherans, and Calvinists, are secretly attached to this system;—the *Arminians*, or Remonstrants, a party which sprung up in Holland, and who differ from the Calvinists in the opinions which they hold concerning the doctrines commonly called the five points;—the *Menno-* Protestantism.

nites, at first known by the name of Anabaptists, and disgraced on account of their fanaticismal excesses, but now the most peaceable of all the sects;—the *Baptists*, a numerous party in America, where they occupy 868 churches. They resemble the Anabaptists, and may be termed moderate Anabaptists;—the United *Moravian Brethren*, or Herrnhutters, a sort of monastic institution, who in other respects adopt the tenets of Lutheranism, and who carry together the blessings of religion and the useful arts into the remotest and most savage tribes;—the *Quakers*, or Tremblers, benevolent enthusiasts, numerous both in America and England;—the *Shakers*, the *Dunkers*, and other associations similar to the Quakers;—the *Swedenborgians*, or followers of the Baron Swedenborg, a sect of mystics to be met with in Sweden and England;—lastly, the *Methodists*, who are distinguished by an extreme *méthod* or strictness in morals, are very numerous in England, and still more so in the United States. Christianity, besides all the enemies which have sprung from its bosom, has seen arise close by its side a rival at first dangerous, and still troublesome, in

Mahometism. *Mahometism*, or, according to the manner in which Mahometans themselves speak of it, *Islamism*, that is the Orthodox church. This religion is merely a confused mixture of Judaism and Christianity, with some poetical ornaments. The Mahometan creed prevails in the greater part of Asia and Africa, as well as in Turkey in Europe, and it is tolerated in Russia. Mahometism comprehends several

Sunnites. sects. The *Sunnites*, although divided with regard to discipline into four parties, agree in reckoning the book of traditions, or the Sunna, in the number of their sacred writings, and in considering Omar and his successors as the legitimate Califs. This party is the most numerous: the Turks belong to it.

Schütes. The name of *Schütes* means Separatists. The Sunnites give it to all those who differ from them; they reckon six classes, each split into twelve subdivisions, which make 72 heretical sects; for the Turks have thought, like Bossuet, that the multiplicity of heretics furnishes a plausible objec-

tion to their doctrines. But in truth, there is only one considerable party amongst the Schütes, that of the followers of Ali, who reject the Sunna: their creed is dominant in Persia.

It is difficult to speak with precision as to the number of followers belonging to each religion actually existing in the world—a misplaced zeal leads the different parties to exaggerate their numbers, as if there were no truth in Seneca's observation, that a great majority often indicates a bad cause [k]. Infidel writers in particular, have thought they were rendering an important service to their cause, by ridiculously exaggerating the numbers of Mahometans and Pagans, not considering that truth will be always truth, whether it be believed by many or by few. Number of individuals of each religion.

The following numbers may be regarded as nearly approaching the truth:

Catholicism,	in Europe. . . 88 millions. out of Europe 28 —	116 millions
The Greek Church,		70
The Protestant Churches, &c.		42
Total of *Christians*.		228 millions.
Judaism,		4 to 5
Mahometism,		100 110
Braminism,		60
Schamanism, or the religion of Dalaï Lama,		50
Buddism, comprising the religion of Fo, &c.		100
Fetichism, and various other beliefs,		100

Languages and religious creeds are the ties of *moral society*, which often survive the fall of *civil and political society*; but it is the latter which determines the boundaries of states and empires, which it is the province of political geography to describe. We must then take a general view of the varied forms of this society.

The ties which unite husband and wife, parents and children, formed the family or domestic society. The relation of master and servant had its origin when society Domestic society.

[k] Argumentum pessimi, turba.

was in this state. The weak not being able to assert their rights, or procure the means of subsistence, must have soon resolved to claim the protection of the strong. Those families that happened to live in the same neighbourhood, would, after quarreling for a while, at last agree to live in harmony together. Certain rules would be established amongst them, not yet to be considered as laws, but as customs. The union of these families did not form a state, but only a civil society. These small societies must soon have perceived that their customs and observances required to be fixed, and to be invested with the character of laws. Men of superior natural capacity became the unlettered lawgivers of these hamlets or villages. As soon as the various relations in which men stood to each other were fixed by laws, political society commenced.

Civil society.

Political society.

But this was a society without government, and soon became a prey to the evils of anarchy. Experience of these evils taught men that a physical force is indispensably requisite to support the laws, which of themselves have a force purely moral. A government is thus established under some form or other. The convention which fixes the original laws of civil society, is called the social compact; that which fixes the existence of the form of a government, and adjusts the circumstances connected with it, is called the constitution. By this last convention, civil society is constituted a state, or, if the term is more agreeable, a republic; for this last word, derived from the Latin, originally signifies every civil society having a government and laws, without reference to the form.

States or republics.

A government is the union of physical force established by the will of civil society to maintain the laws and the constitution. The force of the government, regulated by the established laws, is called the supreme power. The supreme power may be divided into different branches, as, for example, the legislative power, subdivisible into the proposing, the deliberating, and the decerning power; the executive power subdivisible into the administrative, the judicial, the military, and the power of supreme inspection.

Supreme power.

These divisions are partly arbitrary. The manner in which the supreme power is organised, subdivided, and concentrated, is called the form of government. The supreme power represents the national sovereignty, which is nothing but the supreme power not organised, existing in the hands of a civil society without government.

Forms of government are innumerable; but we shall point out those most generally known, by advancing from the state of the greatest physical dissemination of powers, to that of their greatest concentration. These two extremes approach each other more nearly than is imagined. Forms of government.

Pure democracy exists in that state in which the supreme power is immediately exercised by the majority of the nation: this form of government differs from the state of primitive civil society, in which all equally rule. Commissorial democracy is a state in which the supreme power is exercised by a council immediately chosen from the people, revocable, and responsible. Such functionaries are not then the representatives of the nation, but merely its proxies and commissioners. We term a representative democracy that state in which the supreme power is exercised by magistrates, chosen by the people, who represent them, and who, consequently, taken collectively, are sovereign and not responsible. This form is subdivided into a pure representative democracy, when the people themselves directly choose their representatives—and into a representative electoral democracy, where the people chuse electoral bodies, who again elect the representatives. Democracy.

Elective aristocracy resembles representative democracy: It is when the people, either mediately or intermediately, choose their magistrates, not indifferently from among the citizens, but from a certain class determined by law. Elective aristocracy is pure or free, when the people have created the privileged class, or the aristocractic body,—when admission into that body is open to all citizens,—when the members of this body are amenable to the supreme power in the hands of the people. Simple or pure aristocracy is, when the people have chosen once for all, as their pleni- Aristocracy.

potentiary representatives, a body which governs, and which is renewed without the concurrence of the people. Every form of government, compounded of those which we have just named, is called an aristo-democracy. When the aristocratic party seem predominant, we have a temperate aristocracy, when the democratical, we have a temperate democracy. Rome, after the expulsion of the Tarquins, was an hereditary oligarchical aristocracy, which gradually changed into an aristo-democracy, composed of all the other kinds. The Patricians were the hereditary aristocratic body; the senate an elective free aristocracy; the assemblies of the people represented the democracy.

Democratic monarchy. A democratic monarchy is a democracy in which the supreme power is partly exercised by an individual and partly by a democratic body. As the supreme power may be variously divided, it is impossible to ascertain the number of the different kinds of democratical monarchies. It may be hereditary, when the nation has chosen a certain family, or elective, when at each vacancy a monarch is chosen. The right of election may be vested in the people, in an electoral body, in a single elector. These variations are common to other kinds of monarchy. The legislative power may be divided between the commisssioners of the people and the monarch, or it may belong to the former only. The judicial and military powers may be dependent upon the monarch, or upon the body of the nation. The democratic body itself may be chosen without or with the concurrence of the monarch.

Aristocratical monarchy. Aristocratical monarchy is a state in which the supreme power is jointly shared by the monarch and the aristocracy. This latter body may be a free elective aristocracy, when an assembly of representatives chosen by the people from the council of the monarch; an elective hereditary aristocracy chosen by the people, or by the monarch, or by both conjointly; or lastly, a pure and perpetual aristocracy, independent alike of the people and the sovereign. Such were the nobility in the most European states before the present epoch. The aristo-democratic monarchy is a govern-

ment composed of a monarch, of an aristocratic body, and of a democratic body. By a mixed government is generally understood a monarchy of this description. The different combinations of this form are so multiplied that it is impossible to class them.

A pure or absolute monarchy is a state in which the supreme power is entirely confided to one individual, or, in other words, a state in which the majority of the nation is represented by a single individual. Absolute monarchy differs from despotism in this, that the monarch holds his power of the nation, either by expressed or by tacit consent; the despot, on the contrary, pretends to hold his power from God, and from his own sword. The dictatorship was a kind of absolute monarchy, elective and temporary, in the Roman republic. Absolute Monarchy.

The word anarchy literally means the absence of a government. Taking the word government in its true and literal signification, it is evident that anarchy may arise in two ways: 1st, from the non-existence of any supreme power in civil society; 2d, from the preponderance of unconstitutional power, exercised in an arbitrary manner and without the form of a government. Anarchy may be modified in a thousand ways. The following are the forms of it which appear to be most worthy of being defined. Anarchy.

Ochlocracy, or popular anarchy, takes place when a mob or a multitude unlawfully usurp a supreme power. According to this definition, even the majority, when they are not legally constituted sovereign, can exercise only anarchical power. Oligarchy occurs when a small number of individuals or families exercise the supreme power without having been chosen by the constitutional sovereign. It differs then from pure aristocracy. Demagogy is when one or several individuals, without legal appointment, lead and manage the people at their will, actually exercising the power which they seem to leave in the hands of the multitude. The word tyrant signified originally chief or monarch. Virgil employs it more than once in this honourable sense, but it was afterwards limited, to denote him who, Ochlocracy. Oligarchy. Demagogy.

in a republic, had usurped the power of an absolute monarch. This is the ordinary sense of the term in the Greek and Roman authors. The moderns use the term to express violent and cruel abuses of authority in all kinds of government.

Despotism. Despotism has been confounded, sometimes with tyranny, sometimes with absolute monarchy. Despotism is absolute power, which is not derived from a lawful source, and which consequently acknowledges no limits. The despot pretends to be master of his country and of his subjects, just as a private person is proprietor of his estate or his cattle. Despotism is not necessarily tyrannical, or cruel and violent—it is not absolutely incompatible with some administrative forms, and some institutions which properly belong to regular States, or even to Republics.

It would be improper to class with these forms of government, or of anarchy, created by man, the singular state termed theocracy. "It is," say the Theologians, "a government instituted by God himself, and in which the magistrates govern in the name of God." Such was the constitution of the Jewish people—with them theocracy was united first to democracy, and then to monarchy. The popes, in the dark and middle ages, attempted to establish a theocracy upon a great scale.

Theocracy.

Federal system. We have still to notice the federal systems, which are the unions of several independent States, under a superior authority chosen by themselves, and which are invested with powers more or less extensive, to maintain mutual order, and to furnish the means of defence against external enemies. We may term a confederation, of which all the constituent members are on a footing of equality, a democracy of States: Such is that of America. There have been, however, confederations with a chief or presiding power: The late Germanic empire was of this nature. Confederations sometimes have subjects in common: The Swiss had several districts in this manner.

Political geography considers in societies of men, besides the general tie, or the form of government, the particular

ties which bind individuals to society, and which result from the station assigned to these individuals, or from their division into classes and orders.

Origin of the classes of society.

In the most savage state, insulated man procures directly for himself the little which is necessary to supply his wants or to gratify his wishes. As soon as families begin to draw near each other, they unite together for accomplishing their common labours; but when the number of families augments, the society, becoming larger and more powerful, has recourse to the division of labour. The different products of each branch of industry are then reciprocally changed. These exchanges being not without inconvenience, means are sought for to give them facility and dispatch. Some measure, to ascertain the comparative values of the different commodities, is adopted, either some article in general request, as corn or cattle, or some reputed precious substance, such as gold and silver. This token becomes money: the productions become merchandize; and instead of being bartered, they are purchased. Some sagacious observers now perceive that gain is to be got by buying and selling; they become intermediate agents between the consumers of produce and those who raise or work it; and here commence the first rude attempts of commerce. Ere long, the administration of the affairs, and the defence of the territories of the state, become functions too laborious and too complicated to be gratuitously discharged; the functionaries receive a salary, and instead of warriors we have soldiers. At the same time, every inch of ground would receive its master; property of every kind, after having passed from one hand to another—chance favouring some individuals, and address serving others—would at last become fixed. Those who had been unfortunate or unskilful, finding the impossibility of producing any thing by their own efforts, would let out their strength or their dexterity to others. From society thus at last completely constituted, various classes originate.

Productive class.

The productive class comprehends all those who draw from the earth or some other element, any productions use-

ful to society; cultivators of the soil, fishermen, vine-dressers, miners, &c. There are tribes entirely composed of one or more productive classes. Such are the pastoral tribes, or Nomades; the fishermen, or Ichthyophagi. In civilized states, there exists one productive class of a peculiar kind; —the man of science who enlarges the empire of knowledge, and the man of letters, who purifies the taste, or refines the sentiments, or elevates the morals and manners of the age, equally contribute to the production of true national riches of inestimable price and perpetual duration.

Mechanical or operative class.

The operative class consists of those who, by various processes, convert raw produce into artificial produce. When such processes eminently require genius and taste, they obtain the name of the fine arts. When they chiefly demand corporeal strength and dexterity, they are called the mechanic arts. A manufactory is an establishment where an art is conducted on a large scale. The name of *work* seems to denote one of these establishments in which extensive and powerful machinery is employed.

Commercial class.

The commercial class is composed of merchants properly so termed, who buy and sell, either on a great or small scale, the productions of nature and of art; of different kinds of correspondents or agents, who facilitate the execution of purchases and sales; of bankers and brokers, who confine their operations to the representative signs of merchandise; and, lastly, of mariners and carriers, in so far as these are proprietors of their means of conveyance, and do not fall to be ranked under the class of mercenaries.

Class of public officers.

We include in one class the public functionaries, and the officers of the sea and land forces. They are equally invested with a greater or less proportion of the force of the state; they are equally the agents of the supreme power.

Class of mercenaries.

The last class comprehends the mercenaries of every kind who let out their labour to private persons, or chiefly to the community. It is composed of labourers and domestics. This last class is most numerous in the states where luxury prevails

The numerical proportion in which these classes are met with in a state, is one of the most interesting questions of statistics. According to this proportion it is that we decide whether we are to denominate a nation agricultural or commercial.

Classes have their foundation in the very nature of society itself, but castes and orders are created by laws and constitutions. By the word caste is understood an hereditary class, exclusively assigned to one species of occupation. This system of division existed in Persia, Arabia Felix, and Egypt, and it still exists in India. It is accounted for in a satisfactory manner, by referring to the original difference of the primitive tribes, whose union formed the nation. The caste of priests and that of warriors, in Egypt, were probably two clans somewhat organized and disciplined, which had reduced to a state of subjection several tribes of husbandmen and shepherds. The conqueror disdained to intermingle with the vanquished; and the laws afterwards sanctioned and perpetuated a system of separation which accident had originally established[1]. Castes.

The political orders in the states of Europe differ essentially from the castes, in this, that they have no occupation which is exclusively reserved for them, or if they have it, like the clergy, it is not hereditary. In the middle ages, when the armies consisted of cavalry, the order of the nobility partook much of the nature of a caste. The nobles now are merely an order of the state. The citizens, commonalty, or third order, and the peasants, form, in some states, orders recognized by the constitution. In Sweden, the order of peasants possesses much influence. The same was the case in the Tyrol before the late events. There are still, however, some countries, particularly Russia, where the husbandmen, subjected to the yoke of personal slavery, form a real *caste*, condemned to a state of abject and perpetual degradation. Orders of the state.

[1] Compare Heeren, Views of the Politics and Trade of the Ancients. (In German.)

In despotic states, as in Turkey and in China, there are no orders.

Slavery renders all individuals equal. In Europe, it is the "*esprit de corps*," the corporation or professional spirit of the orders of the state,—it is the equilibrium resulting from their various prerogatives and interests, contending with each other, and with the supreme power, which secures political liberty. It is, therefore, in describing Europe that we shall have to explain the institutions of chivalry, the honorary distinctions, and other institutions, whose object it is, either to mark the degrees in the scale of society, or to render the distance between them less felt and less perceptible.

Denominations of sovereignties.

It would be rather uninteresting to enumerate the various denominations which designate the different states. The use of the terms empire, kingdom, sultanat, khanat, and others, will be learnt in the descriptive part of this work. It would be equally useless to consider in this place, the titles which the heads of states assume, from the modest president of the United States, to the vain-glorious Emperor of China, who is called the son of heaven, and who is, however, only the silly imitator of the Persian monarchs, who style themselves kings of kings, princes of the stars, and brothers of the sun and moon [m]. Empty sounds have no influence upon the prosperity or the power of states [n]. Political geography regards, as almost unworthy of notice, the arms and colours by which the different states mark their ensigns, their flags, and their frontier posts.

Resources of the state.

It is a matter of much greater importance to ascertain the material resources of the state. This is the particular object of an extensive science, termed political arithmetic [o]; the results, however, of this science must have a place in the descriptions of political geography.

[m] Ammian. Marcell. xvii. 5. xxiii. 6.

[n] Becmanni, Syntagma Dignitat. Illust. Dissert: iii. cap. 3.

[o] See the works of Young, Petty, &c. quoted p. 551, 552. The general Treatises of Statistics, by Ackenwall, Toze and Mensel, (in German,) and the Statistical Account of Scotland by the Parochial Clergy.

The first element is the value of land, and of its produce. Here the different productions of the three kingdoms of nature are classed according to their usefulness as articles of life, and their value as articles of merchandise. The government itself knows, only by approximation, the value of what agriculture, the fisheries, and the mines produce, and what is the exact proportion between the commodities which the nation sells, and those which it buys. Governments beside, do not often publish even the imperfect information of this kind which they possess. Political geography, therefore, cannot absolutely warrant the accuracy of the lists of productions, of exports, and imports, which it is obliged to collect with so much trouble. To render these details as useful as possible, it is necessary to know the proportional values in which lists of this kind are made up; the monies, the weights, and the measures of each country. This subject, which presents a different aspect in every state, will come to be considered in our particular descriptions. Value of land.

In the second rank, amongst the elements of the national resources, should be placed commercial and manufacturing industry. It was this which accumulated on the rock of Tyre, on the barren coasts of Attica, and on the flat sandy shores of Alexandria, the treasures of the ancient world; and it was it which, in modern times, raised Venice and Holland to greatness. Here political geography should consider the situation of the coasts of a country, the number and nature of its ports, and the state of its great roads and canals; circumstances, all of which directly influence the progress and prosperity of national industry. It is likewise necessary to attend to the various commercial institutions, such as the great national banks, which accomplish the rapid exchange of the signs that represent the value of merchandise, and the commercial and trading companies, amongst which there are some that possess in sovereignty vast provinces beyond the boundaries of Europe. Industry, commerce, manufactures.

Population.

The population of a state forms the third element in its resources. We have seen in a preceding book, that the proportions between the deaths, the births, and the number of living inhabitants, enable us to approximate nearly the population of a country; but it is a census alone which enables us to ascertain it with exactness. Even when we have an authentic census, we should beware of trusting to it with implicit confidence. The same individuals are often counted twice, which happens every time that the inhabitants of the country are numbered in summer, and those of the towns in winter.

The number of inhabitants is the foundation of every good system of finance; the more individuals a country contains, provided they have the means of subsistence, the greater progress will commerce and manufactures make; and consequently the greater the increase of the revenues. The number of inhabitants ought equally to determine the number of the troops. It is computed that the men capable of bearing arms, form about the fourth part of the whole inhabitants. The greatest effort, however, that the most warlike state can make in a case of extreme necessity, is to arm the eighth part of its population. No example even of this has occurred in modern history.

Proportion of population to the extent of territory.

Let us observe also that the more a mass is concentrated, provided that it has free space sufficient to move in, the more energy it will acquire. A small populous country, therefore, is, in proportion, more powerful than a state of vast extent thinly peopled. A country is looked upon as populous, when it contains about 100 inhabitants to the English square mile. England is peopled at the rate of 198 to the square mile; but Ireland and Scotland present a less favourable proportion; the former being 122, and the latter 56; Wales has 80 to the square mile. Holland had, before the troubles of 1788, and the revolutions which followed them, 212 inhabitants for each square mile, which makes 1908 for each square English league. The Island of Malta is probably the most thickly peopled country; it had more than 6000 souls to the square league;

but these are to be regarded only as rare local exceptions. And it is common enough to find, in European Russia, governments which have not more than 20, or even 10 inhabitants, to each square mile [p].

The attempts which political arithmeticians have made to compute the value of the aggregate revenue of a whole nation, arising from the employment of its capital in the cultivation of the soil, and in the various branches of commerce and the arts, have hitherto produced only proximate results, more or less accurate according to the correctness of the data from which the calculations have been made. Political geography merely exhibits the sum of the revenues at the disposal of the government of each state, and the principal sources whence they flow. In many countries this information is furnished by the *annual budget*, which is the name given to the table of finances laid before the aristocratic or democratic body, sharing in the exercise of the supreme power. As the budget, however, is sometimes intended to neutralize the unfavourable impression which may have been made by the increase of the public debts of the state, it occasionally exhibits fallacious details: in absolute monarchies this device is superfluous. But the correct estimates often remain buried in the ministerial *bureaux*, until some lucky chance, or the will of an enlightened sovereign, ushers them into useful publicity. As it is only in Europe that there exists a regular system of finance, it is in the description of that part of the world that we shall point out the different species of taxes and customs, and all the ingenious artifices by which civilized governments force money out of the pockets of their subjects; while the chiefs of barbarous nations carry off, *in kind*, and most frequently in an arbitrary and irregular manner, the articles which they require.

Revenues of the state.

Debts of the State.

An armed force, naval and military, is unfortunately, but necessarily, an object of the first importance to every government.

Armed force.

[p] Busching, Introduction a la connaissance des Etats de l'Europe.

Savage tribes, and even some half-civilized nations, are accustomed to march against their enemies all the males fit to carry arms. Nothing prevents them from doing so, as fishing and hunting are occupations which a horde of savages carry along with them. In other circumstances, the women may be sufficient for the employments of agriculture and the tending of cattle; but as soon as labour is multiplied, and, in consequence of this, comes to be divided, that is, as soon as the agricultural, manufacturing, and commercial classes, have each a separate existence and place in society, it is impossible to arm and to bring into the field the entire mass of a nation, without completely suspending the exercise of those trades and occupations on which its subsistence depends. It therefore becomes necessary to form a class exclusively devoted to the trade of war; such was, in the middle ages, the design of the order of nobility and of chivalry; but the invention of gunpowder and artillery, the introduction of a new system of fortification, and the perfection to which tactics have been brought, have converted the formerly simple and almost mechanical art of war into a profound and extensive science, to the study of which many years must be devoted. This consideration, strengthened by motives of ambition and policy, gradually paved the way for the establishment of standing armies. The European powers have had, for more than a century and a half, a certain number of troops in a state of perfect discipline and equipment, ready to march at a moment's notice. In supporting these troops, one-third, and often one half of all the public revenue is consumed. The land force, or the army, is composed of four principal parts, or arms, with their subdivisions; namely, the infantry, or combatants on foot; the cavalry, or combatants on horse-back; the artillery, whose province is to work those engines of destruction, on the skilful management of which the issue of battle frequently depends; and the engineer department, which conducts the defence and attack of fortified places. In the description of a kingdom, not only should we point out the number and situation of the for-

Land forces.

tresses, the passes and defiles of greatest importance, as well as the number of troops which it maintains; but it is farther necessary to mention, whether these are regular troops, or bands without discipline or military science, and also to specify the physical advantages and disadvantages of the frontiers.

In like manner, it is not enough to know the number of ships of war of which the navy of a state consists. We must also ascertain whether it possesses an adequate number of skilful officers and experienced sailors. We must observe whether it comprehends in its dominions extensive coasts, furnished with safe and commodious harbours, or touches the sea only in some insulated points. According to circumstances, a state requires a fleet of ships of the line, and frigates to fight on the open sea, or a flotilla of gun-boats to defend its coasts, its straits, and its ports. Sea forces. Fleet and flotilla.

Finally, states have also, besides their own peculiar forces, a force of situation depending upon their external relations; and particularly, on the alliances, whether diplomatic or natural, which render them the friends or enemies of each other. The equilibrium resulting from the alliances of the different European nations, is called the "balance of "power." This political equilibrium has frequently been subverted; but it is notwithstanding of importance to examine the principal bases on which it rests, as shall be done in our description of Europe. Force arising from external relations.

The moral state of a nation is the result of all these political and social relations we have been specifying. This state is indicated by various signs, of which the political geographer ought to notice the most striking. Moral state of a nation.

The mode of dress is more than a simple object of curiosity; the loose flowing habit of the orientals, and the tight clothing of the European, exert an influence on their physical and moral constitution. The nudity of certain nations procures to them corporeal advantages, an agility, a strength, and a robustness of health, unknown to nations whose limbs are encumbered with garments; but this superiority is more than counterbalanced by extreme indolence and feebleness, Garments. Dress.

and torpor of understanding. The custom of painting the body, whether by imprinting, or marking figures upon the skin, or by simply besmearing it with a coat of colouring, marks the infancy of civilization, and the first workings of vanity. Rank and dignity are frequently indicated by the vestments, or by the ornaments with which they are embellished. A particular kind of sash of cotton cloth is the distinguishing badge of royalty in Otaheite. The priests of Siam reserve to themselves the privilege of shaving their eyebrows. A necklace of human teeth supplies the place of the star, in the order of negro nobility.

Habitation. The ordinary habitations of a people, are an almost infallible index of the degree of civilization at which they have arrived. The human race may be divided into four classes, according to the four kinds of habitations which follow, 1*st*, Caverns in the rocks, and under ground. They who make these their common abodes, are called Troglodytes. 2*d*, Huts of earth, branches of trees, stones, or some other substance, either in the natural state, or coarsely wrought. 3*d*, Tents; these moveable dwellings, in the opinion of wandering pastoral tribes, appear preferable to our palaces. 4*th*, Houses, which may be defined huts brought to a state of perfection; for even the most superb colonnade, is merely a noble imitation of the coarse beams which supported the thatched roof. We find in Europe, houses constructed of unsquared beams—of beams that are squared and lined with wainscoting—of prepared clay and squared timber—of bricks and wood—of bricks alone—of unhewn stone—of hewn stone—and of marble.

Towns, Country towns, and villages. The name of a city or town, strictly speaking, is not given to a collection of houses on account either of its extent or its population, but in consequence of certain privileges which the place enjoys. The right of exercising the various arts and trades, and of conducting commerce, serves in most countries chiefly to distinguish cities and towns from villages. Villages are sometimes larger than towns, for example in Silesia; but they have commonly no privilege to distinguish them from hamlets and other assemblages

of houses in the country. Burghs are places which enjoy a portion of the rights granted to cities. In other respects, these words admit of different senses, according to the laws and customs of different countries.

Utensils and instruments. Utensils and instruments are objects no less worthy of the attention of a philosophical observer. The bows, the javelins, and the nets of savages, often deserve to be admired for the perseverance and dexterity that were required to produce them.

Food. The European is accustomed to make almost every nutritive substance minister to his support, or to the gratification of his palate. But there are nations that live almost exclusively upon one kind of food. The frugivorous, carnivorous, and ichthyophagous tribes are distributed over the whole surface of the globe. The taste for horse-flesh appears peculiar to the Mongols, Tartars, Finns, and other descendants of the Scythians, and to the Sclavonic and Gothic nations. Both ancient and modern writers place the Acridophagi, or eaters of locusts, in Africa. Some of the American tribes visited by Humboldt, devour a species of clay.

Anthropophagism. Respecting Anthropophagism, or the horrible custom of eating human flesh, it appears to be proved that it does not belong exclusively to any nation; all savage tribes are addicted to it, either from the impulse of a ferocious hatred of their enemies, or by the dictates of an atrocious superstition, or finally, in consequence of extreme want. Not only do modern accounts assert that the practice obtains in the greater part of the nations of Africa, America, and Australasia; but we discover from several passages in the ancients, that it was at one time prevalent in Europe. The poets ascribe it to the Cyclops and Lestrygons, whom they place in Italy [q]. Historians bring this charge against the Scythians [r], the Cimbrians [s], a tribe of Caledonians [t], and other nations of the north.

[q] Homer, Odyss. ix. 290. x. 129.
[r] Herod. iv. 18—20. Plin. vii. 2.
[s] Diodor. v. chap. 32.

The heroes and gods of Homer, employ expressions borrowed from the rites of Anthropophagism; Jupiter reproaches Juno for desiring to eat, either raw or dressed, King Priam and his children. Human sacrifices were known amongst the Greeks and Romans, as well as the Celts, Scandinavians, and oriental nations. These horrid sacrifices appear to have been often succeeded by a repast still more horrid. The disgusting practice of burying the dead bodies of their relations in their own bowels, is attributed to the Issidones [u], and the Massagetæ [x]; to several tribes of India [y]; to the people of Thibet and the Marian Islands [z]; and to the ancient Irish [a].

Inebriating drink.

The desire of procuring a momentary elevation of spirits, has caused the invention amongst all nations, of intoxicating liquors. Their different properties, from the generous wine of Europe to the loathsome ava of the Otaheitans, deserve to be pointed out in the geographical descriptions of the respective countries.

Customs.

From the immense variety of customs, which impart to social life, in every nation, its peculiar features, political geographers select the most striking, namely those which are most closely connected with morals, and which serve to illustrate the history and filiation of the species. Such is the circumcision practised amongst the African nations which do not profess Islamism; the custom of embalming dead bodies, common alike to the Guanches of the Canary islands, and to the ancient Egyptians; the fashion of letting the bodies of the dead dry and wither away in the air, common to the Otaheitans and the ancient Medes; the custom prevalent among the females of India, and the wives of the Wendes and Scandinavians, of immolating themselves upon the tombs of their husbands; and in general the

[t] Hieronym. ap Buchan, Rer. Scotic. ii. p. 65. Edit. Wechel.
[u] Herod. iv. 26.
[x] Strabo, xi. 353, edit. Casaub. Atrob. Herod, i. cap. 216.
[y] Herod, iii. cap. 99, 100.
[z] Rubruquis, Marce Paul. Mendana, &c.
[a] Strabo, iv. 139.

ceremonies observed at marriages, births, and funerals, present resemblances that are often highly interesting.

Civil laws sometimes present singularities which deserve to be marked in the description of a nation. But it is sufficient to notice regulations which punctiliously prescribe the silly ceremonies of a degrading etiquette; punishments revolting to humanity; graduated scales of murders, and mutilations, and tortures; superstitious ordeals, still prevalent amongst different nations, and a thousand other similar observances of ancient barbarism, or the bequeathments of more recent despotism. Civil laws.

The intellectual state of society closes this lengthened view of the various aspects under which nations may be contemplated. Do they possess an accumulated store of the discoveries of genius, and of the observations of wisdom? Do they cherish, in the sublime and beautiful effusions of poetry, the expression of the noblest sentiments of humanity and patriotism? Do men of science and literature occupy the honourable rank to which they are entitled? These are questions which require to be satisfactorily solved before we can determine the progress which a nation has made in civilization and in morals. State of knowledge.

The general result, the collected effect of all these aspects and relations, to which our attention has been drawn, constitutes the character of a nation. Nations may be distributed into three general classes. Savages are those, who are ignorant of the art of writing, or of fixing their thoughts by means of conventional signs equivalent to writing. Their vague and unsteady ideas are attached only to objects which strike their senses; they delight to adorn their persons in a manner which to us appears ridiculous; they are passionately fond of bodily exercise, and in this respect they infinitely surpass us. Their industry is generally confined to a little gardening, to fishing, and the chase. Some of them however, produce specimens of beautiful workmanship, and have even commodious and elegant habitations. The class of barbarians, or men half civilized, comprehends every nation which, by writing, by written Classes of nations. Savages. Barbarians or half civilized.

laws, by a religion expressed in ceremonial observances, or by a more regular military system, has evidently emerged from the savage state. But the information which such a people possesses is as yet only an indigested mass of incoherent observations: their arts are exercised as it were by routine—their policy is limited to the defence of their frontier, at the moment of danger, or to offensive operations conducted without a plan. Their progress is in general slow and uncertain, because, even in advancing towards civilization, they have no proper conception of the great objects at which they should aim. A civilized nation is that which has arranged its knowledge in the form of sciences; which has elevated the mechanical to the rank of the fine arts; which, to express the various sentiments of the human heart, has created the "Belles Lettres;" which is possessed of a fixed system of legislation, of policy, and of war, calculated not only for existing circumstances, but for ages to come—a nation in which Christianity, undefiled by superstition or enthusiasm, displays its proper influence in the purification and elevation of the public morals,— a nation, finally, which recognizes the great principles of public law, by acting in time of peace as the friend of every other state, and by respecting, in time of war, the property of defenceless citizens.

Civilized nations.

Character.

The general character of a nation, being the result of all the physical circumstances in which it is placed, and of the political institutions, which modify these circumstances, it is absurd to make it depend upon climate alone. Extreme cold, as well as extreme heat, by enfeebling the constitution, seems to check and restrain that progress in improvement which a people might otherwise make; but institutions and manners struggle successfully against the climate. Egypt, under the tropic, and Scandinavia, under the polar circle, have equally given birth to heroes, men of genius, and philosophers.

Does it depend on climate?

Nature of a country; its influence.

The nature of a country has more influence than the temperature. The mountainous central parts of Greece, formerly the beloved abodes of courage and independence,

are still the places that are least accessible to despotism. In Thrace, the Sarres, inhabitants of the mountains, maintained for a long time their independence [b]; in these same mountains, as well as in Macedonia, we find at this day hordes of Turcomans who live in the enjoyment of liberty [c]. The Illyrians bravely resisted the kings of Macedonia, and the Roman Legions [d]. The Arnauts, or Albanians wandering upon these same mountains, obey the Turks only when payed by them.

The Greeks, in spite of the yoke of tyranny under which they are oppressed, exhibit still in some mountainous cantons, the manly character and republican spirit of their ancestors. Without mentioning the Mainotes, so often referred to, let us look to the town of Ambelákia, situated on the declivity of Mount Ossa, above Tempé; its inhabitants, as brave as they are industrious, have twice repulsed the Ottoman troops, and no Turk dare shew himself on their rocks. The small town of Parga [e], whose unhappy and unmerited catastrophe we shall afterwards have occasion to describe, has often presented the spectacle of women taking up arms and fighting for liberty [f]. The Spachiotes, who inhabit the white mountains in the Isle of Crete, have been only lately subjugated, rather by intestine discords than by the arms of the Turks. They still preserve several institutions of the ancient Cretans [g]. It is perhaps to the peculiar nature of the soil of Europe, to its being more intersected, more rugged, and more unproductive, than that of Asia or America, that we owe that presence of mind, and that spirit of bold enterprise and perseverance by which the natives are in general so much distinguished. These qualities eminently characterize the inhabitants of the Alps, the Dofrines, and the Cevennes.

[b] Herodot, lib. vii. cap. iii.
[c] Felix Beaujour, vol. i. p. 325.
[d] Livy, i. 43. cap. 19. Justin, &c.
[e] F. Beaujour, vol. i. p. 272.
[f] Scrofani, Voyage en Grèce, vol. iii. p. 21.
[g] Savary, Letters sur la Greece. Lett. xxxvi.

Nations that occupy mountainous districts, especially when jealous of their liberty, and living in small separate states, speak generally a number of dialects, which, in process of time, become so many languages. In Caucasus, there are twenty-six different dialects spoken [h]. As a farther proof of this, we may also refer to the numerous dialects of Greece and Scandinavia.

People inhabiting plains.

Tribes that inhabit vast plains destitute of large rivers and forests, naturally betake themselves to a wandering life, and the tending of flocks and cattle. The patriarchal government, the parent of despotism, had its origin

Nomades.

amongst wandering tribes or *Nomades*. An insulated mode of life retards the progress of population; and the facility with which food is procured, obstructs the growth of industry and the arts. Such is the cause of the barbarism in which the tribes of central Asia remain. But if these tribes meet with considerable rivers, bordered by meadows affording rich pasture to their herds, they follow their course [i],

Fishermen and agriculturists.

and, descending into fertile valleys, become fishermen and agriculturists. As soon as they have fixed their abode, we see the arts and sciences gradually spring up in the midst of them. The Mongols descending from their upland plains, have become the founders of numerous towns in China; and an African horde, following the Nile from Meroe and Upper Ethiopia, has been able successively to create the wonders of Thebes and of Memphis.

Tribes living in Forests.

Forests must have been the primitive abodes of the European tribes, when they lived upon acorns. Even now the palm forests afford shelter to the nations of Africa. The hunting of animals was the natural occupation of these people; but at the dawn of civilization, the tribes of hunters, having both the body and the mind formed by violent exercise, by dangers, and incessant toil, must have made more rapid progress in improvement than the pas-

[h] Strabo, xi. Reineggs, Voyage, &c.

[i] Compare Deguignes, Histoire des Huns, ii. p. 5.

toral tribes, and must have built houses and towns at a much earlier period. The forests would furnish them with the materials and the model of their architecture. Trunks of trees supporting a verdant roof, suggested the first idea of Grecian and Indian colonnades, whilst Chinese architecture consists only of tents imitated in wood and stone; and in the Gothic architecture, we recognise the image of gloomy caverns and steep rocks [k].

Mountains, rivers, and forests, having directed the first tribes in their emigrations, and having influenced their physical and moral character, have also given rise to the first geographical divisions and denominations [l], as we shall often have occasion to show in our particular descriptions. But what has most accelerated the extension of the human species, and the progress of civilization, is the invention of navigation.

Original geographical division.

What lively and strange emotions must the first men have felt, when, descending from their paternal mountains, after having wandered in the thick forests which covered them, they saw, all at once, their further advance impeded by an immense plain of water, which, in the distance, appeared to be lost in the sky, and to mingle with the clouds! The hunters, accustomed as they were to danger, would feel a great degree of repugnance to commit themselves to the waves. But no sooner was the first skiff launched upon the ocean, than the whole physical and moral state of that tribe, which, in consequence of its situation, was enabled to profit by this great discovery, would be changed. A small territory, abounding in fisheries, is enabled to accumulate a numerous population. Civilized islands are asylums inaccessible to the attacks of savages. These small corners of the earth, insulated by nature itself, gave rise to the first ideas of country and of national independence. Even the inclemency of the maritime air must have had

Maritime people.

[k] Hodge's Travels in India, part. i.

[l] Rudbeck, Atlant. i. 55—57. Eccard, Orig. German, p. 86. Torfæi, Hist. Norweg. i. 130—150.

some influence upon the progress of civilization. In the interior of the country, a tent or hut of verdant turf afforded a sufficient shelter from the rain and the wind. Near the sea, the dampness of the atmosphere rendered it necessary to build habitations of firmer materials and a closer construction. Great towns arose upon the banks of a river, or upon the shores of the sea.

Character of insular nations.

The character of insular nations is always distinguished by originality. Attached to their native soil, and unjust towards a foreign one; faithful to national remembrances, but strongly biassed by superstitions and prejudices, they generally exhibit more energetic virtues and vices than the inhabitants of continental plains.

Influence of navigation.

In the history of the human species, the progress of navigation will always hold the first place after that of agriculture. The civilization which agriculture gives rise to, is purely local; it stops as soon as the supply of the wants of the nation is secured; agricultural societies, generally composed of only two classes, masters and slaves, insulate themselves from the rest of the world more by their laws and customs, than by the lofty walls they have sometimes raised to defend themselves against foreign aggression. But navigation disturbs this Chinese felicity, and interrupts a repose so opposed to the destinies of human nature. A vessel unites the most distant regions of the world; cities, nay even whole nations, are transported to other climates; the tumult and the hum of civilization is heard amongst indolent savages; an universal movement pervades all classes; and man is unconsciously drawn on to the conquest of the globe.

The fate of the great human families has been decided by the direction which they took in their emigration, by the nature of the soil which they occupied, but, above all, by the positions of the great seas of the globe, and the advantages which men were able to derive from them. Is not the perpetual infancy of the Chinese chiefly owing to their ignorance of the art of navigation? On the contrary,

if the Japanese and the Malays exhibit a character, manly, enterprising, and different from that of the other Asiatics, it was formed at the epoch when their squadrons traversed the great eastern Ocean, which is at present filled with their colonies. The people of Africa are, as it were, buried in the midst of a great continent, destitute of gulphs and arms of the sea. This circumstance, by hindering navigation from carrying industry thither, has powerfully contributed to brutify the nations of that continent. The Europeans alone were called by Providence to extend their empire over the globe. The nations who have peopled Europe had to cross the mountains of Caucasus and of the Alps, the Black Sea, the Baltic, the Archipelago, the Adriatic, and the Mediterranean. Obstacles so formidable, retarded them at first in their progress; but, at the same time, they served to develope and to fortify that character of activity and courage which is common to the European nations. The descendants of Canaan, the Phenicians, soon lost the empire of the sea; Athens rivalled Tyre; a Grecian city ruled over conquered Egypt; Carthage submitted to Rome; Europe seized the sceptre of the world. At this first epoch, all civilization was collected around the Mediterranean; it was almost the only sea upon which there was any navigation. A second epoch commenced, and the march of civilization was still intimately connected with the progress of navigation. The compass and Columbus appeared. A new world saw our vessels land on its shores. A new Europe has arisen, and continues to advance with giant steps in the career of improvement. The Atlantic ocean has become what the Mediterranean was before, the great highway and thoroughfare of civilized nations.

Civilization spread around the Mediterranean.

Civilization spread around the Atlantic ocean.

But the march of civilization is far from being terminated; the wonders we have witnessed may still be surpassed. The Europeans have not confined themselves to the shores of that Atlantic ocean which, immense as it appeared to the Phenician and the Greek navigators, is only an arm of the sea, compared to that great ocean which, under the names

Views upon the great ocean.

of the Indian, the Pacific, and the Eastern, extends from pole to pole. The American navigators have already crossed the whole of this aquatic hemisphere—already British colonists have begun to settle the innumerable islands which form, to the south-east of Asia, a fifth part of the world; and Australasia, the most delightful country of the globe, will probably, ere many ages pass away, have reached the highest pinnacle of civilization. Let another Cadmus carry thither that torch of science which enlightens Europe! Let colonists, fraught with our learning, found a new Greece in Otaheite, or the Pelew Islands, then those rising grounds, which now produce only aromatic herbs, will be covered with towns and palaces; bays now shaded by a forest of palms, will display a forest of masts; gold and marble will be extracted from the bowels of mountains as yet untouched by the miner; coral and pearls will be dragged from the bottom of the sea to adorn the new capitals; and one day, perhaps, Europe, Asia, Africa, and America, will find dangerous and successful rivals in countries, whose existence, at this moment, scarcely occupies their attention.

Thus, in the history of the human race, the past, the present, and the future, are connected with the position of the great seas of the globe, and with the progress of navigation.

TABLES.

TABLES

OF

MATHEMATICAL GEOGRAPHY.

I.

COMPARISON OF FRENCH AND ENGLISH WEIGHTS AND MEASURES.

Units which form the Bases of the New French System compared with the Weights and Measures of England.

		English.	
The Metre	=	3,2809167	feet, or 39,371 inches.
Are	=	1076,441	square feet.
Litre	=	61,028	cubic inches.
Stere	=	35.317	cubic feet.
Gramme	=	15,4441	grains troy.
Gramme also	=	5,6481	drams avoirdupois.

New Weights and Measures of France compared with the Old, and also with English Weights and Measures.

Linear Measure.

	French Feet.	English Feet.
Distance from the Equator to the Pole	30784440	32809167
Degree (centesimal)	307844,4	328091,67
Myriametre	30784,44	32809,167
Kilometre	3078,444	3280,9167
Hectometre	307,8444	328,09167
Decametre	30.78444	32,809167
METRE	3,078114	3,2809167

	Lines French.	Lines English.
Decimetre . .	44,3296	47.2452
Centimetre . .	4,43296	4,72452
Millimetre . .	0,443296	0,472452

Square or Superficial Measure.

	French Square Feet.	English Square Feet.
Miriare	9476817,46113	10764414,3923
Kilare .	947681,746113	1076441,43923
Hectare .	94768,1746113	107644,143923
Decare .	9476,81746113	10764,4143923
ARE .	947,681746113	1076,44143923
Deciare .	94,7681746113	107,644143923
Centiare .	9,47681746113	10,7644143923

	Square Inches.	Square Inches.
Square Decimetre .	13,646617	15,500756

	Square Lines.	Square Lines.
Square Centimetre .	19,651134	22,321088
Square Millimetre .	0,19651134	0,2232108

Measures of Capacity.

	French cubic feet.	English cubic feet.
Myrialitre . .	291,738519	353,1714693
Kilolitre } Metre cube } .	29,1738519	35,31714693
Hectolitre . .	2,91738519	3,531714693

	Cubic inches.	Cubic inches.
Decalitre . .	504,124160	610,280264
LITRE ou Decimetre cube	50,4124160	61,0280264
Decilitre . .	5,04124160	6,10280264

	Cubic lines.	Cubic lines.
Centilitre . .	871,126926	1054,564296

The Litre, which is the unit for measures of capacity = 2,113 English pints, wine measure; and therefore the Hectolitre equals 26,4 such gallons — 35 litres = a Winchester bushel.

Solid or Cubic Measures.

	French cubic feet.	English cubic feet.
Decastere . .	291,738519	353,1700
STERE (metre cube) .	29,1738519	35,3170
Decistere . .	2,91738519	3,5317

This measure is used for fire-wood, stone, &c. The stere is the same as the kilometre in the preceding measure.

Weights.

	Poids de Marc. livres.	on.	gros.	grains.	English Troy weight. lb.	oz.	dr.	gr.
Bar or cubic, Metre of water	2042	14	0	14	2681	3	6	2,
Myriagramme	20	6	6	63,5	26	9	15	1,46
Kilogramme	2	0	5	35,15	2	8	3	12,146
Hectogramme	.	3	2	10,715		3	4	8,414
Decagramme	.		2	44,2715			6	10,441
GRAMME . . .				18,82715				15,4441
Decigramme . .				1,882715				1,54441
Centigramme . .				0,1882715				0,15444

French New Measure of Time compared with the Old or Usual System.

New division.	Old value. H.	M.	S.
1 second .	0	0	0.864
100 seconds, 1 minute .	0	1	26.4
100 minutes, 1 hour . .	2	24	0.
10 hours, 1 day . .	24	0	0.

Reversed.

Old or usual division.	New value. H.	M.	S.
1 second .	0	0	1.1574
60 seconds, 1 minute .	0	69	54.4
60 minutes, 1 hour . .	1	15	74.
24 hours, 1 day . .	10	0	0.

French New Measure of the Circle compared with the old or Common System.

New division.	Old value.		
100 seconds, 1 minute of space,	0°	0′	$32''\frac{2}{5}$
100 minutes, 1 degree,	0	54	0
100 degrees, 1 quadrant,	90	0	0
400 degrees, 1 circle,	360	0	0

Reversed.

Old division.	New value.		
60 tierces, 1 second,	0°	0′	$3''\frac{3}{81}$
60 seconds, 1 minute of space,	0	1	$85\frac{5}{47}$
60 minutes, 1 degree,	1	11	$11\frac{1}{9}$
90 degrees, 1 quadrant,	100	0	0
4 quadrants, or 360°, 1 circle,	400	0	0

Old Weights and Measures of France.

LONG MEASURE.—The toise or fathom of France is equal to six feet French, the foot to 12 inches French, and the inch to 12 lines, each subdivided into 12 points; 76 French feet are nearly equal to 81 English feet; or, more accurately, 40,000 French feet, inches, or lines, equal 42,638 English feet, inches or lines. Thus 1 French foot equals 1.06597 English, or 12,78934 English inches; and hence one English foot equals 11,26 French inches. The Paris aune was $46\frac{1}{10}$ English inches.

In the old French road measure, the lieue, or league, is two French miles, each mile 1000 toises; hence the French league equals two English miles, three furlongs, and 15 poles.

The French league, however, in different parts of France, has been applied to different distances. The marine league, (20 to a degree,) equals 2853 toises, or 6081 English yards; and the astronomical league, (25 to a degree,) equals $2282\frac{2}{7}$ French toises, or 1865 English yards.

The arpent, or acre of land, contained in general 100 square perches; but the perch varied in different provinces.

The old French weight for gold and silver (called poids de marc,) makes the pound or livre contain 2 marcs, 16 onces, 128 gros, 384 deniers, or 9216 grains.

The French marc = 3780 grains Troy weight.

For commercial weight, the poids de marc was likewise used, and the quintal of 100 livres = 108 lb. avoirdupois, very nearly.

Weights and measures, however, varied considerably in the different provinces.

Corn measure was the muid of 12 setiers, 24 mines, 48 minots, or 144 bushels.

Wine measure was the muid of 36 setiers, 144 quartes, or 288 pints.

II.

Synoptical Table of the Planetary System[a].

Diameters and bulk; those of the earth considered as unity.

	Diameter.	Bulk or Value.
The Sun	111.45	1,384,462.
Mercury	0.4012	0.06456
Venus	0.9693	0.8902
The Earth	1.	1.
The Moon	0.2731	0.02036
Mars	0.5199	0.1406
Vesta	0.4	. . .
Juno	0.1	. . . .
Ceres	0.3076	0.02913
Pallas	0.154	0.00365
Jupiter	10.862	1.281.
Saturn	9.983	.995
Uranus	4.332	80.49

	Rotation, or Sidereal Day. Hours.	Min.	Sec.	*Flattening at the Poles.*
Mercury	24	5	28	
Venus	23	21	0	
The Earth	23	56	4	$\frac{1}{111}$
Mars	24	39	21	$\frac{1}{16}$
Jupiter	9	56	0	$\frac{1}{14}$
Saturn Herschel	10	16	0	20.91 : 22.81
Saturn Calandillo	11	39	0	13.3 : 16.1

	Revolutions Tropical, Yrs.	Days.	Hrs.	Min.	Sec.	*Sidereal.* Days.	Hrs.	Min.	Sec.
Mercury	0	87	23	14	32.7	87	23	15	43.6
Venus	0	224	16	41	27.5	224	16	49	10.6
The Earth	1	0	5	48	48	365	6	9	8
Mars	1	321	22	18	27.4	686	23	30	35.6
Vesta	3	240	.	.	.	.	.	.	.
Juno	4	130	.	.	.	.	.	.	.
Ceres	4	221	.	.	.	.	.	.	.
Pallas	4	241	17	.	.	.	.	.	.
Jupiter	11	315	14	39	2	4,332	14	27	10.8
Saturn	29	161	19	16	15.5	10,759	1	51	11.2
Uranus	83	294	8	39	.	30,689	.	29	.

[a] Laplace, Système du Monde. Biot, Astronomie Physique.

Half the greater Axis of the Orbits of the Planets; or their mean distances from the Sun, in Myriametres, each containing 32809 *English feet.*

	Myriametres.
Mercury,	5917938
Venus,	11058215
The Earth,	15287873
Mars,	23294021
Vesta,	36278123
Juno,	40619979
Ceres,	42282000
Pallas, [b]	42666000
Jupiter,	79511907
Saturn,	145836700
Uranus,	291720130

The relative proportion of the eccentricity to the half of the greater axis.

Mercury,	0.205523
Venus,	0.006885
The Earth,	0.016814
Mars,	0.093088
Ceres,	0.082501
Pallas,	0.2463
Jupiter,	0.018077
Saturn,	0.056223
Uranus,	0.046683

Inclination of the Orbit to the Ecliptic.

Mercury,	6°	35′	30″
Venus,	3	23	10
The Earth,	0	0	0
Mars,	1	50	47
Ceres,	10	36	57
Pallas,	34	50	40
Jupiter,	1	19	38
Saturn,	2	30	40
Uranus,	0	46	12

[b] The eccentricity of Pallas proves, that, notwithstanding the identity almost of its mean distance with that of Ceres, the orbits of these two planets are very distant from each other at their aphelion and perihelion. Between these points, the orbits intersect each other. Pallas sometimes approaches Jupiter and sometimes Mars.

III.

Table of Climates.

Climates of Half an Hour.	Longest Day.		Latitude.		Extent of Climates.	
Their Number.	*Hours.*	*Min.*	*Degrees.*	*Min.*	*Degrees.*	*Min.*
0	12	0	0	0	0	0
1	12	30	8	34	8	34
2	13	0	16	43	8	9
3	13	30	24	10	7	27
4	14	0	30	46	6	46
5	14	30	36	28	5	42
6	15	0	41	21	4	53
7	15	30	45	29	4	8
8	16	0	48	59	3	30
9	16	30	51	57	2	58
10	17	0	54	28	2	31
11	17	30	56	36	2	8
12	18	0	58	25	1	49
13	18	30	59	57	1	32
14	19	0	61	16	1	19
15	19	30	62	24	1	8
16	20	0	63	20	0	56
17	20	30	64	8	0	48
18	21	0	64	48	0	40
19	21	30	65	20	0	32
20	22	0	65	46	0	26
21	22	30	66	6	0	20
22	23	0	66	20	0	14
23	23	30	66	28	0	8
24	24	0	66	32	0	4

Climates of Months.	Longest Day.	Latitude.		Extent of Climates.	
Their Number.	*Months.*	*Degrees.*	*Min.*	*Degrees.*	*Min.*
1	1	67	23	0	51
2	2	69	10	2	27
3	3	73	39	3	49
4	4	78	31	4	52
5	5	84	5	5	34
6	6	90	0	5	55

N. B.—We do not in these Tables take any notice of the effects of the refraction, which increases the duration of the day, particularly towards the poles. Under the pole itself the refraction alone, independent of the twilight, increases the day, which is six months long 67 hours.

IV.

Table of the Decrease of the Degrees of Longitude, according to the ancient or nonagesimal graduation, the Earth being supposed to be spherical.

Latitudes.	Degree of Longitude. In toises of 6 ft. Fr.	Degree of Longitude. In nautical miles.	Latitudes.	Degree of Longitude. In toises of 6 ft. Fr.	Degree of Longitude. In nautical miles.	Latitudes.	Degree of Longitude. In toises of 6 ft. Fr.	Degree of Longitude. In nautical miles
0	57050	60.00	31	48901	51.43	61	27659	29.09
1	57041	59 99	32	48381	50.88	62	26784	28.17
2	57015	59.96	33	47846	50.32	63	25904	27.24
3	56972	59.92	34	47298	49.74	64	25010	26.30
4	56911	59.85	35	46732	49.15	65	24110	25.36
5	56833	59.77	36	46154	48.54	66	23204	24 41
6	56738	59.67	37	45562	47.92	67	22291	23.44
7	56625	59.56	38	44956	47.28	68	21371	22.48
8	56495	59.42	39	44337	46.63	69	20445	21.50
9	56347	59.26	40	43703	45.96	70	19512	20.52
10	56183	59.09						
			41	43056	45.28	71	18573	19.53
11	56002	58.89	42	42397	44.59	72	17629	8.54
12	55803	58.69	43	41725	43.83	73	16679	17.54
13	55587	58.46	44	41038	43.16	74	15724	16.54
14	55355	58.22	45	40340	42.43	75	14764	15.53
15	55106	57.95	46	39630	41.68	76	13801	4.51
16	54840	57.67	47	38908	40.92	77	12833	13.50
17	54557	57.38	48	38174	40.15	78	11862	12.48
18	54257	57.06	49	37429	39.36	79	10885	11.45
19	53941	56.73	50	36671	38.57	80	9907	10.42
20	53609	56.38						
			51	35902	37.76	81	8924	9.38
21	53260	56.01	52	35123	36.94	82	7941	8.35
22	52895	55.63	53	34333	36.11	83	6953	7.32
23	52514	55.23	54	33532	35.27	84	5963	6.28
24	52117	54.81	55	32722	34.41	85	4972	5.23
25	51705	54.38	56	31902	33.55	86	3980	4.18
26	51276	53 93	57	31076	32.68	87	2986	3.14
27	50832	53.46	58	30231	31.79	88	1991	2.09
28	50372	52.97	59	29384	30.90	89	996	1.05
29	49897	52.47	60	28525	30.00	90	0	0.00
30	49406	51.96						

V.

Table of the Decrease of the Degrees of Longitude, according to the New or Centesimal Graduation, the Earth being considered as Spherical.

Latitude.	Degree of Longitude.	Latitude.	Degree of Longitude.	Latitude.	Degree of Longitude.
Deg.	*Kilometres.*	*Deg.*	*Kilometres.*	*Deg.*	*Kilometres.*
0	100,000	34	86,074	68	48,175
1	99,988	35	85,264	69	46,793
2	99,951	36	84,433	70	45,339
3	99,889	37	83,581	71	43,994
4	99,803	38	82,708	72	42,578
5	99,692	39	81,815	73	41,151
6	99,556	40	80,902	74	39,115
7	99 396	41	79,968	75	38,268
8	99,211	42	79,015	76	36,812
9	99,002	43	78,043	77	35,347
10	98,769	44	77,051	78	33,874
11	98,511	45	76,040	79	32,392
12	98,229	46	75,011	80	30,902
13	97,922	47	73,963	81	29,404
14	97,592	48	72,897	82	27,899
15	97,237	49	71,813	83	26,387
16	96,858	50	70,711	84	24,869
17	96,456	51	69,591	85	23,344
18	96,029	52	68,455	86	21,814
19	95,579	53	67,301	87	20,279
20	95,106	54	66.131	88	18,738
21	94,608	55	64,945	89	17,193
22	94,088	56	63,742	90	15,643
23	93,544	57	62,524	91	14,090
24	92,978	58	61,291	92	12,533
25	92,388	59	60,042	93	10,973
26	91,775	60	58,778	94	9,411
27	91,140	61	57,500	95	7,846
28	90,483	62	56,208	96	6,279
29	89,803	63	54,902	97	4,711
30	89,101	64	53,583	98	3,141
31	88,377	65	52,250	99	1,571
32	87,631	66	50,904	100	0,000
33	86,863	67	49,546		

VI.

Table of the Decrease of the Degrees of Longitude, according to the New or Centesimal scale, the Earth being supposed to be a Spheroid, flattened $\frac{1}{333}$.

Latitude.	Degree of Longitude.	Latitude.	Degree of Longitude.	Latitude.	Degree of Longitude.
Deg.	*Metres.*	*Deg.*	*Metres.*	*Deg.*	*Metres.*
0	100149.4	34	86269.5	68	48358.3
1	100137.1	35	85461.0	69	46972.4
2	100100.3	36	84631.4	70	45574.8
3	100038 9	37	83780 9	71	44165.9
4	99953.	38	82909 7	72	42746.0
5	99842 5	39	82018.1	73	41315.3
6	99707.6	40	81106.2	74	39874 4
7	99548.2	41	80174.1	75	38423 4
8	99364.3	42	79222.3	76	36962 8
9	99156.2	43	78250.9	77	35493.0
10	98923.6	44	77260.1	78	34014.2
11	98666 8	45	76250.1	79	32527.0
12	98385.8	46	75221.3	80	31031.6
13	98080.6	47	74173.8	81	29528 5
14	97751.3	48	73108.0	82	28017.9
15	97398.1	49	72024.0	83	26500.3
16	97020.9	50	70922.1	84	24976.1
17	96616.9	51	69802.6	85	23445.6
18	96195.1	52	68665 8	86	21909.2
19	95746.8	53	67512.0	87	20567.3
20	95274.9	54	66341.3	88	18820.3
21	94779.6	55	65154.2	89	17268.6
22	94260.9	56	63950.9	90	15712.6
23	93719.1	57	62731.7	91	14152.6
24	93154.2	58	61496.8	92	12589.0
25	92566.4	59	60246.7	93	11022.3
26	91955.8	60	58981.5	94	9452.9
27	91322.6	61	57701.6	95	7881.0
28	90666.4	62	56407.4	96	6307.2
29	89988 9	63	55099.1	97	4731.8
30	89288.6	64	53777.1	98	3155.7
31	88566.4	65	52441.7	99	1577.8
32	87822.4	66	51093.1	100	0.0
33	87056.7	67	19731.8		

VII.

Of the Decrease of the Degrees of Latitude, according to the New or Centesimal Scale, the Earth being supposed to be a spheroid, flattened $\frac{1}{111}$.

Latitude.	Degree of Latitude.	Latitude.	Degree of Latitude.	Latitude.	Degree of Latitude.
Deg.	*Metres.*	*Deg.*	*Metres.*	*Deg.*	*Metres.*
0	99552.5	34	99789.7	68	100245.9
1	99552.9	35	99802.2	69	100257.5
2	99553.8	36	99814.9	70	100269.0
3	99555.1	37	99827.8	71	100280.2
4	99556.9	38	99840.9	72	100291.1
5	99559.0	39	99854.1	73	100301.7
6	99561.8	40	99867.5	74	100312.0
7	99564.7	41	99881.0	75	100322.0
8	99568.2	42	99894.6	76	100331.7
9	99572.1	43	99908.3	77	100341.1
10	99576.4	44	99922.1	78	100350.1
11	99581.2	45	99936.0	79	100358.8
12	99586.3	46	99950.0	80	100367.2
13	99591.8	47	99964.0	81	100375.1
14	99597.8	48	99978.0	82	100382.7
15	99604.2	49	99992.1	83	100389.9
16	99610.9	50	100006.2	84	100396.8
17	99618.0	51	100020.3	85	100403.2
18	99625.4	52	100034.4	86	100409.3
19	99633.1	53	100048.4	87	100414.9
20	99641.6	54	100062.4	88	100420.1
21	99650.2	55	100076.3	89	100424.9
22	99659.1	56	100090.2	90	100429.3
23	99668.4	57	100103.9	91	100433.2
24	99678.0	58	100117.6	92	100436.8
25	99687.9	59	100131.2	93	100439.9
26	99698.1	60	100144.6	94	100442.5
27	99708.6	61	100157.9	95	100444.7
28	99719.4	62	100171.0	96	100446.5
29	99730.5	63	100184.0	97	100447.8
30	99741.9	64	100196.8	98	100448.7
31	99753.5	65	100209.4	99	100449.2
32	99765.3	66	100221.7	100	
33	99777.4	67	100233.9		

VIII.

Comparative View of Linear Measures, called (or equivalent to) Feet.

States and Towns.	Measures.	Lines.	Decimetres.
Amsterdam	Voet	125.5	2.83
Augsbourg	Stadt, or Werk-Schu	131.3	2.97
Bâle	Stadt, or Feldt-Schu	132.2	2 98
Batavia	Voet	139.1	3.14
Berlin	Fuss of Berlin	137.3	3.10
	Fuss of the Rhine	139.1	3.14
Brabant	Fuss	126.6	2.86
Cadix	Pie	125.3	2.83
China	Foot of the Merchants	150	3.38
	Mathematical foot	147.7	3.35
	Ché or Carpenter's foot	143.1	3.23
	Land-surveyor's foot	141.7	3.19
Copenhagen	Fod	139.1	3.14
Cracovia	Foot	158	3.56
Dantzick	Fuss	127.2	2.86
Dauphiné	Pied	151.1	3.41
Dijon	Pied	139.2	3.15
Dresden	Fuss	125.5	2.83
France	Pied de Roi	144	3.25
	Decimetre	44.33	1
Frankfort on the Maine	Fuss	127	2.86
Franche Comté	Pied	158.3	3.57
Genoa	Palmo	111.3	2.51
Hamburgh	Fuss of Hamburgh	127	2.86
	Fuss of the Rhine	139.1	3.14
Leipzic	Fuss	125.3	2.83
Lisbon	Palmo	96.9	2.18
London	Foot	135	3.05
Lorraine	Pied	129.2	2.92
Lubeck	Fuss	129	2.91
Madrid	Codo	187.9	4.23
	Pies	125.3	2.83
	Palmo great	93.97	2.11
	Palmo small	31.32	0.70
Malacca	Common foot	139.1	3 14
	Carpenter's foot	127.5	2.87
Messina	Palmo	107.3	2.42
Milan	Palmo	176	3.97

VIII.—*Continued.*

States and Towns.	Measures.	Lines.	Decimetres
Munich	Fuss	128.2	2.89
Naples	Palmo	116.5	2.63
Normandy	Pied	132	2.98
Norway	Fod	139.1	3.15
Nuremberg	Stadt-Schu of Carpenters	134.7	3.03
	Werk-Schu of Masons	123.6	2.78
Padua	Palmo	189.9	4.28
Paris	Pied-de-Roi	144	3.25
Palermo	Palmo, ancient	107.3	2.42
Prague	Fuss of Bohemia	131.4	2.97
	Fuss of Moravia	131.2	2.96
Riga	Fuss	125.5	2.74
Rome	Palmo	130.6	2.94
Russia	Foot	135	3.05
Sardinia	Palmo	110.1	2.48
Sweden	Fot	131.6	2.97
Switzerland	Fuss	133	3.00
Stuttgard	Fuss	126.8	2.85
Turin	Palmo	227.7	5.13
Venice	Palmo	153.7	3.46
Vienna	Fuss	143	3.23
Warsaw, duchy of,	Fuss	158	3.56

IX.

A comparative View of the Agrarian Measures used in the principal States of Europe, in ancient French square Feet, (pieds de roi,) *compared with the Arpent fixed by the Government for measuring the Lakes and Forests, and with the Hectare, or new Agrarian Measure of France.*

States and Places.			Square Feet.	Arpents.	Hectares.
Alsace,	Morgen		19.045	0.39283	0.2009
Austria,	Jochart		54.571	1.12750	0 5758
Bavaria,	Juchart		31.709	0.65495	0.3345
Denmark,	Toende Hartkorn		104.854 to 210.514	2.16640 to 4 34946	1.1064 to 2.2213
England,	Acre		38.376	0.79289	0.4049
France,	Arpent of lakes & forests[a]		48.400	1.00000	0.5107
	Arpent of Paris		32.400	0.66941	0.3418
	Arpent, common		40.000	0.82645	0.4220
	Hectare		94.768	1.95801	1.0000
	Are[b]		00.9471	0.01958	0.0100
Hanover	Vorling		12.326	0.25467	0.1300
	Drohn		18.490	0.38202	0.1951
	Morgen		24.653	0.50935	0.2601
Holland,	Morgen		77.016	1.59124	0 8126
Italy,	Rome	Rubbio	175.138	3.61857	1.8480
		Quarta	43.784	0.90464	0.4620
		Pezza	25.020	0.51694	0.2639
	Milanese, Pertia		7.127	0.14725	0.0752
	Naples, Moggia		31.679	0.65453	0.3342
	Tuscany	Saccate	46.986	0.97078	0.1957
		Stioro	5.546	0.11459	0 0585
	Venice, 1000 Passi		28.456	0.38792	0.3002

[a] This Arpent contained 100 square perches of 22 feet square, or 484 square feet.

[b] The Are, which is the unity of the new French agrarian measures, is equal to ten metres, or one square decametre, that is, a space containing one hundred square metres. The Hectare is a space containing 100 ares, or a square hectometre.

In comparing the new and old measures of France, we may make use of the following approximations.

21 = 47 Arpents of lakes and forests.
27 = 79 Arpents of Paris, of 18 feet to the perch.
19 = 45 Arpents, common, of 20 feet to the perch.
67 = 82 Ares of Normandy, of 160 perches of 22 feet each.

IX.—*Continued.*

States and Places.			Square Feet.	Arpents.	Hectares.
Lorraine,	Journal		40.328	0.83323	0.4255
Piedmont,	Giornata		36.005	0.74390	0.3799
Prussia,	Great Hufe		4,613.130	33.32913	17.0218
	Hakenhufe		107.542	2.22195	1.1347
	Landhufe		53.771	1.11097	0.5674
	Morgen	great	53.771		
		small	24.197	0.49993	0.2553
Russia,	Dasaetina		109.782	2.26756	1.1584
Saxony,	Acker		52.247	1.07948	0.5513
Spain,	Yugada		1,345.032	27.78993	14.1928
	Fanega		32.521	0.67191	0.3431
	Cahizada		195.124	4.03149	2.0589
	Aranzada		10.781	0.22274	0.1137
Swabia,	Jouchart		13.299	0.27477	0.1403
Sweden,	Tunna-land		46.773	0.96639	0.4935
Switzerland,	Berne, Juchart	for woods	36.6661	0.75755	0.3869
		for land	32.592	0.67338	0.3439
	Zurich, Juchart	for land	30.711	0.63452	0.3240
		for woods	34.12	0.70495	0.3600
Tyrol,	Jauch, or Jauchart		40.999	0.84707	0.4326

X.

A comparative Table of Itinerary and Topographical Measures, considered, first, as measures of distance in their relation to a degree (nonagesimal) of the Equator; to a Geographical French League, of 25 to a degree; and to the Kilometre (1000 Metres;) and, secondly, as measures of superficial extent in their relation to Geographical square Leagues of Germany (15 to a degree,) of square Leagues of France, (25 to a degree,) and to a square Kilometre.

ITINERARY PROPORTIONS.			MEASURES.	TOPOGRAPHICAL PROPORTIONS.		
				Square Leagues.		
To an equatorial degree.	Leagues of 25 to a degree.	Kilometres.		Fifteen to a degree.	Twenty-five to a degree.	Square Kilometres.
12	2.08353	9.27083	Great Meile of Germany . . .	1.5625	4.3389	85.951
15	1.666	7.41666	Common, or Geographical Meile . .	1.	2.777	53.004
17.75	1.4084	6.2676	Small Meile	0.714	1.987	39.2753
69.5	0.3616	1.6094	Mile of England	0.0471	0.13075	2.5889
60	0.4167	1.8542	Mile, Geographical, of ditto . .	0.0625	0.17363	3.4373
20	1.25	5.5625	League, marine, of ditto . .	0.5625	1.5625	30.9357
33	0.7576	3.371	Lieue of Anjou	0.2066	0.5739	11.3636
57.125	0.4371	1.9449	League of Arabia	0.0687	0.191	3.78
28	0.8929	3.9732	Lieue of Artois	0.2868	0.7973	15.785
17.333	1.4423	6.4183	Lieu, Astronomical	0.7489	2.079	41.2

105.6	0.2367	1.0535	Pfase of Batavia and of Java,	0.02018	0.005602	1.109
26.397	0.9471	4.2145	Horaire of ditto,	0.3229	0.897	17.759
16.087	1.55405	6.9155	League of ditto,	0.8694	2.4149	47.823
33	0.7576	3.371	Lieue of Beauce,	0 2066	0.5739	11.3636
26	0.9615	4.2788	Lieue of Berry,	0.3328	0.9245	18.308
16	1.5625	6.953	Meile of Bohemia,	0.8789	2.44	48.344
21.521	1.1617	5.1693	Lieue of Burgundy,	0.4858	1.3502	26.7186
20	1.25	5.5625	Meile of Brabant,	0.5625	1.5625	30.9414
17	1.4706	6.5441	League of Brazil,	0.7785	2.1638	42.8239
33	0.7576	3.371	Lieue of Bretagne,	0.2066	0.5739	11.3636
28	0.8929	3.9732	League of Cayenne,	0 2868	0.7973	15.7847
28.54	0.8759	3.898	League of Canada,	0.2762	0.7672	15.1944
35	0.71429	3.17857	League of the Carnatic, (Hindostan,)	0.1837	0.5102	10.1
192.4	0.1299	0.5782	Li of China,	0.006078	0.01687	0.3343
11	2.2727	10.1136	Gros or Gau of Coromandel,	1.859	5.1663	102.2856
14.77	1.6926	7.5321	Mile of Denmark,	1.0315	2.866	56.731
12.333	2.027	9.002	Meile of Dresden or Saxony,	1.479	4.1087	81.036
28.54	0.8759	3.898	Lieue, Post (12,000 feet) of France	0.2762	0.7672	15.1944
25	1	4.45	Lieue, geogr. or common,	0.36	1	19.8025
20	1.25	5.5625	Lieue, marine of ditto,	0.5625	1 6625	30.9414
22.25	1.1236	5	Lieue, mean of ditto,	0.4544	1.2633	25
11.125	2.2472	10	Myriametre, or new great league,	1.818	5.049	100

X.—*Continued.*

ITINERARY PROPORTIONS.			MEASURES.	TOPOGRAPHICAL PROPORTIONS.		
				Square Leagues.		
To an equatorial degree.	Leagues of 25 to a degree.	Kilometres.		Fifteen to a degree.	Twenty five to a degree.	Square Kilometres.
11.25	0.2247	1	Kilometre, or new small league,	0.01818	0.05049	1
19.025	1.3139	5.8476	Lieue of Gascogne,	0.6216	1.7266	34.194
26.838	0.9315	4.1452	League of Guiana,	0 3124	0.8677	17.181
	1.3158	5.855	Meile of Holland,	0.6232	1.7319	34.281
13.333	1.875	8.34375	Meile of Hungary,	1.266	3.5159	69.622
42.75	0.5848	2.6023	Cos or Coru of Hindostan,	0.1231	0.342	6.7718
40	0.625	2.78125	Mile of Ireland,	0.1416025	0.3907	7.735
3	8.333	37.0833303	Tingmannaleid of Iceland,	2.5	69.444	1375 1736
9	2.777	12.3601	Mil, marine of ditto,	2.778	7.716	152.797
12	2.0833	9.2708	Mil, common of ditto,	1.5625	4 3389	85.96
58 48	0.4275	1.9024	Lega of Bologna, Italy,	0.06579	0.1828	5.619
67.25	0.3718	1.65427	Lega of Milan,	0.04975	0.1383	2.7366
57.71	0.4332	1.9277	Lega of Naples,	0.06756	0.1877	3.716
74 7	0.3347	1.4719	Lega of the Roman States,	0.0403	0 1121	2.1667
68.25	0.3663	1.62967	Lega of Tuscany,	0.0483	0.1342	2.6558
60.62	0.4124	1.8352	Lega of Venice,	0.06123	0.17009	3.368
12.44	2 001	8 9429	Meile of Lithuania,	1.454	4.004	79.977
28	0.8929	3.9732	Meile of Luxembourg,	0.2863	0.79727	15.7847
23	1.087	4.83696	Lieue of Lyons,	0.4253	1.18157	23.396

10	2.5	11.125	Gros or Gau of Malabar,	1.25	6.25	123.7656
17	1.47066	6.5441	League of the Mysore,	0.7786	2.164	42.824
10	2.5	11.125	Mile of Norway,	2.25	6.25	123.7656
24	1.0417	4.6354	Lieue of Perche, (in France),	0.3906	1.0857	21.491
12.5	2	8.9	Farasange of Persia,	1.44	4	79.21
48	0.5208	2.3177	Lega of Piedmont,	0.09766	0.27123	5.373
24	1.0417	4.6354	Lieue of Poitou,	0.3906	1.0857	21.491
20	1.25	5.5625	League of Poland,	0.5625	1.5625	30.9414
18	1.3889	6.18056	Legua of Portugal,	0.6914	1.9293	38.199
14.37	1.7328	7.7488	Meile of Prussia,	1.089	3.003	60.045
19.025	1.3139	5.8476	Lieue of Provence,	0.6216	1.7266	34.194
104.25	0.2396	1.06714	Werste, common of Russia,	0.0207	0.05741	1.1385
104.716	0.23874	1.0624	Werste, fixed of Russia,	0.0205	0.057	1.1278
110.4	0.22645	1.0077	Werste of M. Trescot of Russia,	0.0192	0.05128	1.014
17.453	1.43244	6.3744	Mile, geographical of 6 werstes,	0.7387	2.05	40.63
12.29	2.0342	9.0521	Meile of the Police of Saxony,	1.49	4.1371	81.939
50	0.5	2.225	Mile of Scotland,	0.09	0.25	4.9506
28.942	0.8638	3.8438	Roé-ning of Siam,	0.2686	0.74615	14.77
17.18	1.4552	6.475	Meile of Silesia,	0.7623	2.117	41.93
16.4	1.5	6.675	Legua nueva of Spain,	0.8117	2.25	44.5556
20	1.25	5.5625	Legua horaria of Spain,	0.5625	1.5625	30.9414
26.4	0.9375	4.17187	Legua juridica of Spain,	0.3164	0.8789	17.4056
10.4	2.4038	10.6971	Mile of Sweden,	2.08	5.7792	114.45
10	2.5	11.225	Gos, or Gau of Surat,	2.25	6.25	123.7656
26.838	0.9315	4.1452	League of Surinam,	0.3124	0.8677	17.181
66.4	0.375	1.6687	Berri of Turkey,	0.05062	0.1406	2.786
28.537	0.8761	3.8985	Lieue of Touraine,	0.2763	0.7676	15.195
10	2.5	11.225	Meile of the Circle of Westphalia,	2.25	6.25	123.76525

XI.

A Table of the different Measures of Antiquity.

Itinerary Measures.	French Measures.	
	Kilometres.	Metres.
The Schœne of middle Egypt	20.	
The Schœne of the Thebaide, or the Indian Gau, known under the name of Stathma	10.	
The Schœne of the Delta = 9,600 paces	6.66	
The Parasang = 7,200 paces	5.	
The Indian Coss = 3,600 paces	2.66	
The Egyptian Mile = 2,880	2.	
The Persian or Asiatic Mile	1.5	
The Hebrew Mile	1.166	
The Pythian or Delphic Stadium		148.148148
The mean Stadium, called also the Nautical or Persian		166.4
The great Alexandrian or Egyptian Stadium		222.22
The Phileterian or Royal Stadium		210.1 4
The Grecian Olympic Stadium		185.37
The Stadium of Eratosthenes		159.2
The Stadium of Cleomenes		133.47
The Stadium of Aristotle, or small Stadium		99.8

Linear Measures.	Metres.	Millimetres.
The royal Cubit of Babylon		468 8
The mean Cubit		416 66
The Pygon or Palmipes		347.22
The Pythian or Delphic foot		277.77
The Palmus Major		086.8
The common Palm, or Palestum		069 3
The Inch, or Uncia of the geometrical foot		023.1482
The Dactylus or Digit		017.361
The Olympic Hecatonpede	30.	864.
The Exapode	1.	851.

XI.—*Continued.*

Linear Measures.	Metres.	Millimetres.
The cubit, of 18 olympic inches,	. .	463
The olympic foot,		308.6
The exapode of six Roman feet,	1.	. . .
The great pace (ὀργυια) of five Roman feet,	1.	. . .
The common pace, of two Roman feet,	. .	. . .
The Roman foot,	. .	. . .

Agrarian Measures.	Square Metres.
The Pletheron=100 square Olympic feet,	9.526
The Exapode=36 square Olympic feet,	3.429
The Saltus of four Centuries,	20.22716
The Century of 100 Heredies,	50.5679
The Heredy of two Jugera,	5056.79
The Jugerum of 800 Exapodes,	2528.395

XII.

Comparative View of the Principal Winds.

COMPASS OF FOUR WINDS.

Grecian Names.	Modern Names.	Situation upon the Compass. Degrees.	
Boreas	North	0	See Homer, Odyss. b. v. l. 295.
Euros	East	90	
Notos	South	180	
Zephyros	West	270	

COMPASS OF EIGHT WINDS.

Grecian or Roman Names.	Modern Names.	Situation upon the Compass. Degrees.	
Boreas; Aparctias; Septentrion	North	0	See the explanation of the Temple of the Winds at Athens, in Vitruvius, l. i. cap. 6. Arist. Meteor. l. ii. cap. 6. Pliny II. 262. Aulus Gellius II. 42, &c.
Cæsias; Aquilo; (sometimes Boreas)	North-East	45	
Apeliotes; Subsolanus (qu. Eurus)	East	90	
Euronotos; Vulturnus (often, Eurus)	South-East	135	
Notos; Auster	South	180	
Libs; Africus	South-West	225	
Zephyrus; Favonius	West	270	
Corus; Skiron; Argestes	North-West	315	
Boreas, &c.	North	360	

COMPASS OF TWELVE WINDS.

Ancient Names.	Modern Names nearly *.	Situation upon the Compass. Degrees.	
Aparctias; Septentrio (Boreas)	North	0	See Arist. *De Mundo*, Pliny, II. 22. Seneca, Nat. Quæst. v. 16. For the compass of 24 winds founded upon this of 12, see Saumaise. Exercit. Plinian. 878—892.
Meses (often Boreas and Aquilo)	N.E. ¼ N.—3° ¾	30	
Cæsias	N.E. ¼ E.+3° ¾	60	
Apeliotes; Subsolanus	East	90	
Eurus; Vulturnus	S.E. ¼ E.—3° ¾	120	
Phœnix; Euronotus	S.E. ¼ S.+3° ¾	150	
Notus; Auster	South	180	
Libonotus; Libophœnix	S.W. ¼ S.—3° ¾	210	
Libs; Africus	S.W. ¼ W.+3°	240	
Zephyros; Favonius	West	270	
Iapix; Corus; Argestes	N.W. ¼ W.—3° ¾	300	
Thracias; Cercias	N.W. ¼ N.+3° ¾	330	
Aparctias	North	360	

* In reckoning from the north round the compass, we can thus better understand the arrangement. Navigators reckon by quarters of circles only, in going from the north to east, or to west, and the same from the south to east, or to west.

XII.—*Continued.*

COMPASS OF THIRTY-TWO WINDS.

English Names.	French Names.	Italian Names.	Situation upon the Compass.
North (N.)	Nord (N.)	TRAMONTANA	0
N. by E.	N. ¼ N.E.	¼ di T. Verso greco	11¼
N.N.E.	N.N.E.	Greco-Tramontana	22½
N.E. by N.	N.E. ¼ N.	¼ di Greco Verso T.	33¾
N.E.	N.E.	Greco	45
N.E. by E.	N.E. ¼ E.	¼ di Gr. Verso Levante	56¼
E.N.E.	E.N.E.	Greco-Levante	67½
E. by N.	E. ¼ N.E.	¼ di Levante V. Greco	78¾
East (E.)	EST.	LEVANTE	90
E. by S.	E. ¼ S.E.	¼ di Liv. Verso Scirocco	101¼
E.S.E.	E.S.E.	Levante-Scirocco	112½
S.E. by E.	S.E. ¼ E.	¼ di Scirocco V. Levante	123¾
S.E.	S.E.	SCIROCCO	135
S.E. by S.	S.E. ¼ S.	¼ di Scir. Verso Ostro	146¼
S.S.E.	S.S.E.	Ostro-Scirocco	157½
S. by E.	S. ¼ S.E.	¼ di Ostro V. Scirocco	168¾
South (S.)	SUD.	OSTRO	180
S. by W.	S. ¼ S.O.	¼ di Ostro V. Libeccio	191¼
S.S.W.	S.S.O.	Ostro-Libeccio	202½
S.W. by S.	S.O. ¼ S.	¼ di Libeccio V. Ostro	213¾
S.W.	S.O.	Libeccio	225
S.W. by W.	S.O. ¼ O.	¼ di Lib. V. Ponente	236¼
W.S.W.	O.S.O.	Ponente-Libeccio	247½
W. by S.	O. ¼ S.O.	¼ di Ponente V. Libeccio	258¾
West (W.)	OUEST.	PONENTE	270
W. by N.	O. ¼ N.O.	¼ di Ponente V. Maestro	281¼
W.N.W.	O.N.O.	Maestro-Ponente	292½
N.W. by W.	N.O. ¼ O.	¼ di Maestro V. Ponente	303¾
N.W.	N.O.	MAESTRO	315
N.W. by N.	N.O. ¼ N.	¼ di Maestro V. Tramontana	326¼
N.N.W.	N.N.O.	Maestro Tramontona	337½
N. by W.	N. ¼ N.O.	¼ di Tram. V. Maestro	348¾
North	Nord.	TRAMONTANA	360

Professor Leslie, to whose liberality the publishers are indebted for the following tables, (XIII. and XIV.) says, "I have been able, after a delicate and patient research, to fix the law which connects the decrease of temperature with the altitude. If B and b denote the barometric pressure at the lower and upper stations; then will $\left(\frac{B}{b} - \frac{b}{B}\right) 25$ express, on the centigrade scale, the diminution of heat in ascent. Hence, for any given latitude, that precise point of elevation may be found, at which eternal frost prevails. Put $x = \frac{b}{B}$ and $t =$ the standard temperature; then $\left(\frac{1}{x} - x\right) 25 = t$, or $x^2 + .04\ tx = 1$, which quadratic equation being resolved, gives the relative elasticity of the air at the limit of congelation, whence the corresponding height is determined. From these data the following table has been calculated.

This table (XIII.) will facilitate the approximation to the altitude of any place, which is inferred either from its mean temperature, or its depth below the boundary of perpetual congelation. The decrements of heat at equal ascents are not altogether uniform, but advance more rapidly in the higher regions of the atmosphere. At moderate elevations, however, it will be sufficiently near the truth, to assume the law of equable progression, allowing in this climate (56° N.) one degree of cold by Fahrenheit's scale for every ninety yards of ascent, and for every hundred yards in the tropical regions.

Dr. Francis Buchanan Hamilton found the temperature of a spring at Chitlong, in the Lesser Valley of Nepal, to be 14°.7 centigrade. But the mean temperature in the parallel of 27° .8′ being 22°.8, the density of the atmosphere corresponding to difference 8.1, is 8510, which gives 1500 feet for the corrected altitude.

XIII.

Table of the Decrease of Temperature according to the Altitude.

Latitude.	Mean temperature at the level of the Sea.		Height of Curve of Congelation. Feet.	Latitude.	Mean temperature at the level of the Sea.		Height of Curve of Congelation. Feet.
	Centigrade.	Fahrenheit.			Centigrade.	Fahrenheit.	
0	29°.00	84°.2	15207	46°	13°.99	57.2	7402
1	28.99	84.2	15203	47	13.49	56.3	7133
2	28 96	84.1	15189	48	12.98	55.4	6865
3	28 92	84.0	15167	49	12.43	54.5	6599
4	28.86	83.9	15135				
5	28.78	83.8	15095	50	11.98	53.6	6334
6	28.68	83.6	15047	51	11.49	52.7	6070
7	28.57	83.4	14989	52	10.99	51.8	5808
8	28.44	83.2	14923	53	10.50	50.9	5548
9	28.29	82.9	14848	54	10.02	50 0	5290
				55	9.54	49.2	5034
10	28.13	82.6	14764	56	9.07	48.3	4782
11	27.94	82.3	14672	57	8.60	47.5	4534
12	27.75	82.0	14571	58	8.14	46.6	4291
13	27.53	81.6	14463	59	7.69	45.8	4052
14	27.30	81.1	14345				
15	27.06	80.7	14220	60	7.25	45 0	3818
16	26.80	80.2	14087	61	6.82	44.3	3589
17	26.52	79.7	13947	62	6.39	43.5	3365
18	26.23	79.2	13798	63	5.98	42.8	3145
19	25.93	78.	13642	64	5.57	42.0	2930
				65	5.18	41.3	2722
20	25.61	78.1	13478	66	4.80	40.6	2520
21	25.28	77.5	13308	67	4.43	40 0	2325
22	24.93	76.9	13131	68	4.07	39.3	2136
23	24 57	76.2	12946	69	3.72	38.7	1953
24	24.20	75.6	12755				
25	23.82	74.9	12557	70	3.39	38.1	1778
26	23.43	74.2	12354	71	3.07	37.5	1611
27	23.02	73.6	12145	72	2.77	37.0	1451
28	22.61	72.7	11930	73	2.48	36.5	1298
29	22.18	71.9	11710	74	2.20	36.0	1153
				75	1.94	35.5	1016
30	21.75	71 1	11484	76	1.70	35.1	887
31	21.31	70.3	11253	77	1.47	34.6	767
32	20.86	69.5	11018	78	1.25	34.2	656
33	20 40	68.7	10778	79	1.06	33 9	552
34	19.93	67 9	10534				
35	19.46	67.0	10287	80	.87	33.6	457
36	18.98	66.2	10036	81	.71	33.3	371
37	18.50	65.3	9781	82	.56	33.1	294
38	18.01	64.4	9523	83	.43	32.8	226
39	77.51	63.5	9263	84	.32	32.6	167
				85	.22	32.4	117
40	17.02	62.6	9001	86	.14	32.3	76
41	16.52	61.7	8738	87	.08	32.2	44
42	16.02	60.8	8473	88	.04	32.1	20
43	15.51	59.9	8206	89	.01	32.0	5
44	5.01	59.0	7939	90	.00	32.0	0
45	14.50	58.1	7671				

*** Dr. Brewster, in Part I. Vol. IX. of the Edinburgh Philosophical Transactions, gives the following formula for ascertaining the mean temperature in a given latitude, in the old world. If T denote the mean temperature in any given latitude, and 81°.5 the observed temperature on the equator, the formula becomes

$$T = 81°.5 \cos. \text{lat.}$$

Table of Mean Temperatures.

Places.	Lat.	Obs. T.	Cal. T.	Difference.
Equator	0° 0′	81° 50′	81° 50′	
Rome	41. 54	60. 44	60. 66	0° 22′ +
Paris	48. 50	51. 89	53. 65	1. 76 +
London	51. 30	50. 36	50. 74	0. 38 +
Edinburgh	55. 58	46. 23	45. 64	0. 59 +
Stockholm	59. 20	42. 26	41. 57	0. 69 —
Abo	60. 27	40. 00	40. 28	0. 28 +
Uleo	65. 3	33. 26	34. 38	1. 12 +
Melville Island	74. 47	1. 33	21. 40	20. 07 +

XIV.

Table of the most Remarkable Heights in different Parts of the World, expressed in English Feet. The Altitudes measured by the Barometer are marked B, while those derived from Geometrical Operations, and taken chiefly from the Observations of General Mudge, are distinguished by the letter G.

	Feet.	
Snæ Fiall Jokull, *on the north-west point of Iceland,*	4558	G
Hekla, *volcanic mountain in Iceland,* . .	3950	G
Sulitelma, *in Lapland,*	5910	B
Nuppi Vara, *the highest of the table-land in Lapland,*	2655	B
Lommijauri, *elevated lake in Lapland,* . .	2265	B
Driftstue, *the highest pastoral hamlet in Norway.* .	2457	B
Snöhätta, *centre of the Norwegian mountains,* .	8120	B
Hardbacke, *Alpine ridge of Norway,* . .	4575	B
Pap of Caithness, ...	1929	
Ben Nevis, *Inverness-shire, highest mountain in Scotland,*	4358	G

	Feet.
Cairngorm, *Inverness-shire,*	4080 B
Cairnsmuir *upon Deugh, Galloway,*	2597 G
Ben Lawers, *west side of Loch Tay, Perthshire,*	3944 G
Ben More, *Perthshire,*	3870 B
Ben Lui, *or* the *Calf, near Tyndrum,*	3651 G
Schihallien, *Perthshire,*	3513 G
Ben Voirlich, *near Loch Earn,*	3207 G
Ben Ledi, *near Callender, Perthshire,*	2863 G
Ben Achonzie, *head of Glen Tilt,*	3028 G
Ben Lomond, *near Aberfoil, Stirlingshire,*	3191 G
Cobbler, *near Arrochar,*	2863 G
Ben Clach, *in the Ochils, above Alloa,*	2359 G
Lomond Hills, east and west, *Fifeshire,*	1466 and 1721 G
Soutra Hill, *on the ridge of Lammermuir,*	1716 G
Coulter Fell, *Lanarkshire,*	2440 G
Carnethy, *high point of the Pentland ridge,*	1700 B
Tintoc Hill, *Lanarkshire,*	2306 G
Leadhills, *the house of the Director of the mines,*	1280 B
Broad Law, *near Crook Inn, Peebles-shire,*	2741 G
Queensberry Hill, *Dumfries-shire,*	2259 G
Cairnsmuir of Fleet, *Galloway,*	2329 G
Hart Fell, *near Moffat,*	2635 G
Dunrich Hill, *Roxburghshire,*	2421 G
Eldon Hills, *near Melrose, Roxburghshire,*	1634 G
Whitcomb Hill, *Peebles-shire,*	2685 G
Lother Hill, *Dumfries-shire,*	2396 G
Ailsa Rock, *in the Firth of Clyde,*	1103 G
Crif Fell, *near New Abbey, Kirkcudbright,*	1831 G
Kells Range, *Galloway,*	2659 G
Goat Fell, *in the Isle of Arran,*	2865 G
Paps of Jura, south and north, *in Argyleshire,*	2359 and 2470
Snea Fell, *in the Isle of Man,*	2004 G
South Berule, *in Isle of Man,*	1584 G
Macgillicuddy's Reeks, *County of Kerry,*	3404 G
Sliebh Donard, *the highest of the Mourne Mountains,*	2786 G
Helvellyn, *Cumberland,*	3055 G
Skiddaw, *Cumberland,*	3022 G
Saddleback, *Cumberland,*	2787 G
Whernside, *Yorkshire,*	2384 G
Ingleborough, *Yorkshire,*	2361 G
Shunnor Fell, *Yorkshire,*	2329 G

	Feet.
Snowdon, *Caernarvonshire,*	3571 G
Cader Idris, *Caernarvonshire,*	2914 G
Beacons of Brecknock,	2862 G
Plynlimmon, *Cardiganshire,*	2463 G
Penmaen Mawr, *Caernarvonshire,*	1540 G
Malvern Hills, *Worcestershire,*	1444 G
Cawsand Beacon, *Devonshire,*	1792 G
Rippin Tor, *Devonshire,*	1549 G
Brocken, *in the Hartz-Forest, Hanover,*	3690
Priel, *in Upper Austria,*	7000 B
Peak of Lomnitz, *in the Carpathian ridge,*	8870 B
Terglou, *in Carniola,*	10390 B
Mont Blanc, *Switzerland,*	15646 G
Village of Chamouni, *below Mont Blanc,*	3367 G
Jungfrauhorn, *Switzerland,*	13730
St. Gothard, *Switzerland,*	9075
Hospice of the Great St. Bernard,	8040 B
Village of St. Pierre, *on the road to Great St. Bernard,*	5338 B
Passage of Mont Cenis,	6778 B
Cross Glockner, *between the Tyrol and Carinthia,*	12780 B
Ortler Spitze, *in the Tyrol,*	15430
Rigiberg, *above the Lake of Lucerne,*	5408
Dôle, *the highest point of the chain of Jura,*	5412 B
Mont Perdu, *in the Pyrenees,*	11283
Loneira, *in the department of the high Alps,*	14451
Peak of Arbizon, *in the department of the high Pyrenees,*	8344
Puy de Dome, *in Auvergne,*	4858 G
Mont d'Or,	6202 G
Summit of Vaucluse, *near Avignon,*	2150
Village on Mont Genevre,	5945 B
St. Pilon, *near Marseilles,*	3295 G
Soracte, *near Rome,*	2271 G
Monte Velino, *in the kingdom of Naples,*	8397 G
Mount Vesuvius, *volcanic mountain beside Naples,*	3978
Ætna, *volcanic mountain in Sicily,*	10936 B
St. Angelo, *in the Lipari Islands,*	5260
Top of the Rock of Gibraltar,	1439 B
Mount Athos, *in Rumelia,*	3353
Diana's Peak, *in the Island of St. Helena,*	2692
Peak of Teneriffe, *one of the Canary Islands,*	12358 B

	Feet.
Ruivo Peak, *the highest point of Madeira,*	5162
Table Mountain, *near the Cape of Good Hope,*	3520
Chain of Mount Ida, *beyond the plain of Troy,*	4960
Chain of Mount Olympus, *in Anatolia,*	6500
Italitzkoi, *in the Altaic chain,*	10735
Awatsha, *volcanic mountain in Kamtchatka,*	9600
The Volcano, *in the Isle of Bourbon,*	7680
Ophir, *in the centre of the Island of Sumatra,*	13842
St. Elias, *on the Western coast of North America,*	12672
White Mountain, *in the State of Massachusets,*	6230 B
Chimborazo, *highest summit of the Andes,*	21440 B
Antisana, *volcanic mountain in the kingdom of Quito,*	19150 B
Shepherd station on that mountain,	13500 B
Cotopaxi, *volcanic mountain in the kingdom of Quito,*	18890 B
Tonguragua, *volcanic mountain, near Riobomba,*	16579 B
Rucu de Pichincha, *in the kingdom of Quito,*	15940 B
Heights of Assuay, *the ancient Peruvian road,*	15540 B
Peak of Orizaba, *volcanic mountain east from Mexico,*	17390 G
Lake of Toluca, *in the kingdom of Mexico,*	12195 B
City of Quito,	9560 B
City of Mexico,	7476 B
Silla de Caraccas, *part of the chain of Venezuela,*	8640 B
Blue Mountains, *in the Island of Jamaica,*	7431
Pelée, *in the Island of Martinique,*	5100
Morne Garou, *in the Island of St. Vincent's,*	5050

In this list of altitudes, I have not ventured to insert the Himalaya or Snowy Mountains, the Imaus of the ancients, or Great Central Chain of Upper Asia, to which some late accounts from India would assign the stupendous elevation from 23,000 to 27,000 feet. Such at least are the results of observations made with a small sextant and an artificial horizon, at the enormous distance of 226 or 232 miles, as computed indeed from very short bases. But even with the best instruments, and under the most favourable circumstances, the determination of minute vertical angles is, from the influence of horizontal refraction, liable to much uncertainty. The progress of accurate observation has uniformly reduced the estimated altitudes of mountains. More recent statements accordingly diminish those heights near 2000 feet.

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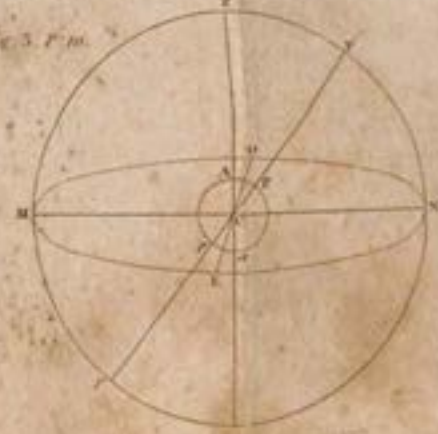

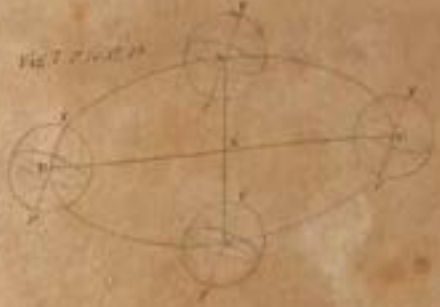

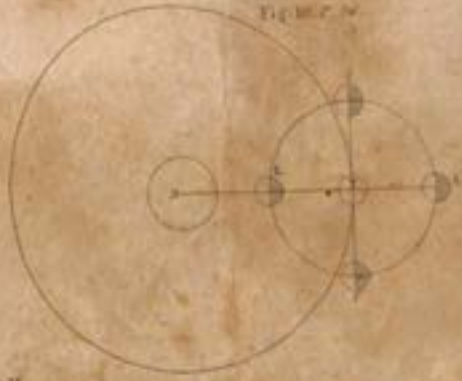

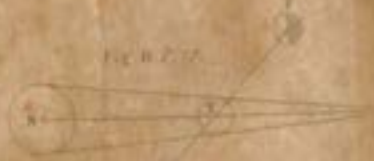

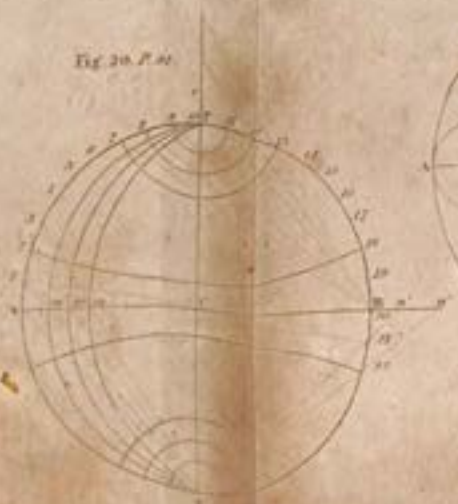

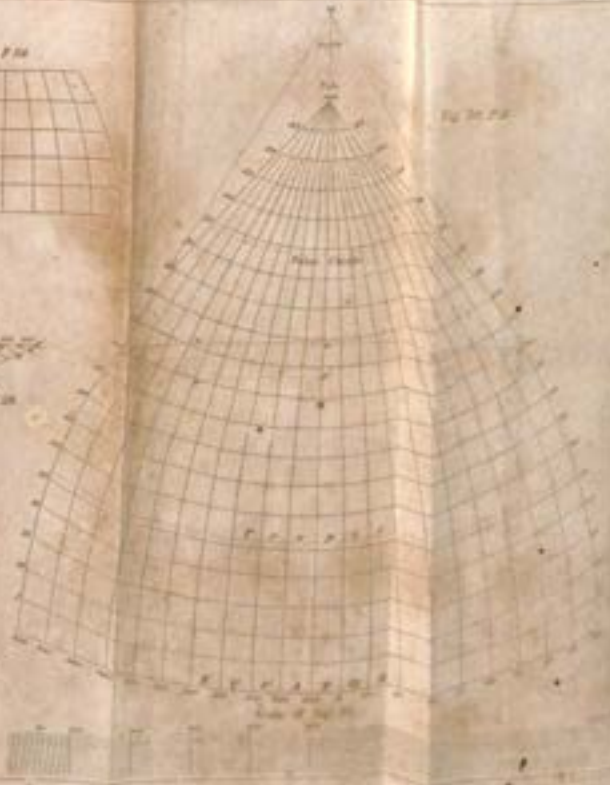

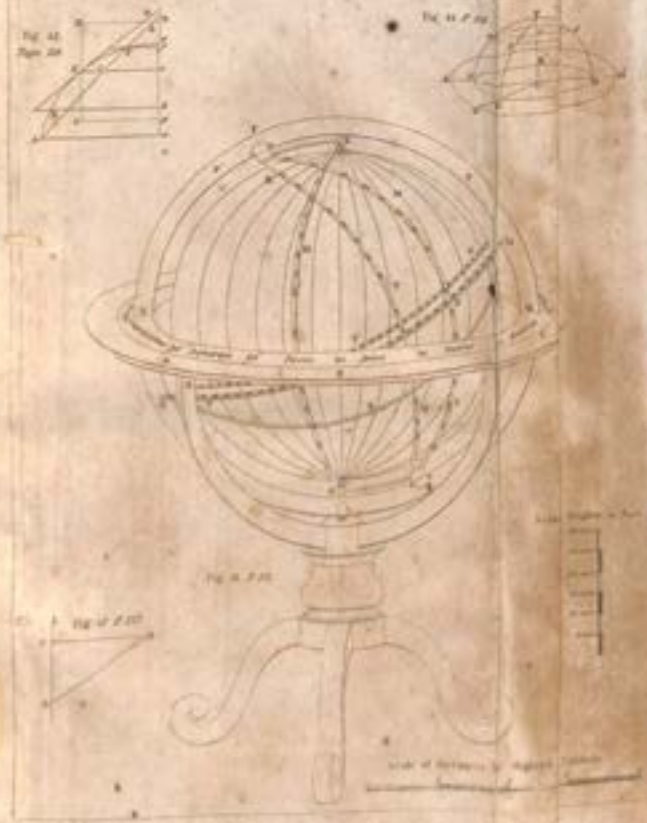

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